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FOR ENGINEERS, ELECTRICIANS
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Presenting in simplest, concise form the fundamental principles, rules and applications of applied electricity.

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Design, construction, operation and maintenance of modern electrical machines and appliances.

Based on the best knowledge and experience of applied electricity.

by FRANK D. GRAHAM, B.S., M.S., M.E., E.E.

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Foreword

This series is dedicated to Electrical Progress—to all who have helped and those who may in the coming years help to bring further under human control and service to humanity this mighty force of the Creator.

The Electrical Age has opened new problems to all connected with modern industry, making a thorough working knowledge of the fundamental principles of applied electricity necessary.

The author, following the popular appeal for practical knowledge, has prepared this progressive series for the electrical worker and student; for all who are seeking electrical knowledge as a life profession; and for those who find that there is a gap in their training and knowledge of Electricity.

Simplicity is the keynote throughout this series. From this progressive step-by-step method of instruction and explanation, the reader can easily gain a thorough knowledge of modern electrical practice in line with the best information and experience.

The author and publishers here gratefully acknowledge the hearty and generous help and co-operation of all those who have aided in developing this helpful series of Educators.

The series will speak for itself and "those who run may read."

The Publishers.

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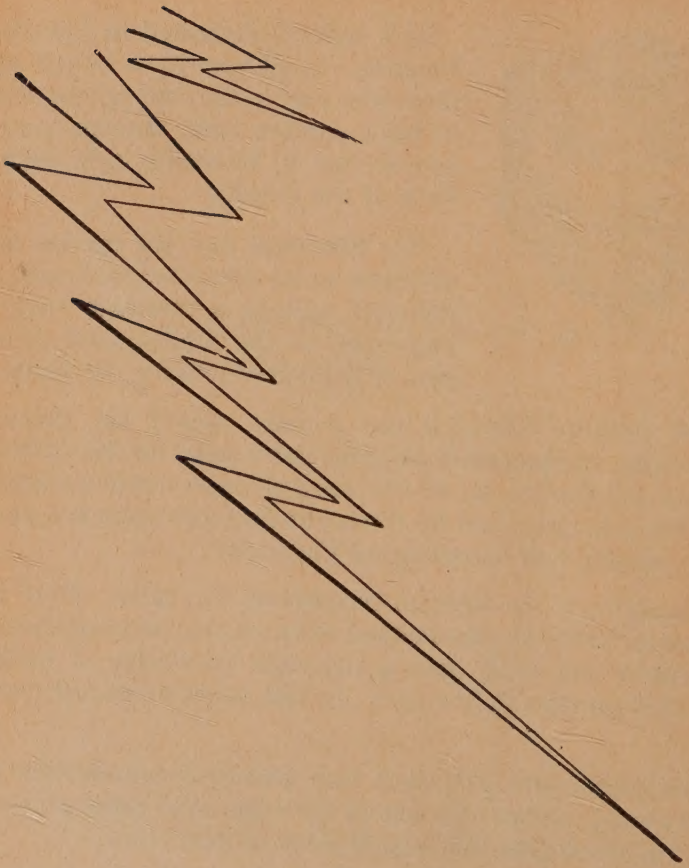

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Finder

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To quickly and easily find information on any subject, read over the general chapter headings as shown in the large type—this brings the reader's attention to the general classification of information in this book.

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"An hour with a book would have brought to your mind,
The secret that took the whole year to find;
The facts that you learned at enormous expense,
Were all on a library shelf to commence."

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CHAPTER 130

Electric Railway Systems

Any system of electric car propulsion includes besides the track and rolling stock, suitable apparatus: 1, to produce the current, and 2, to transmit and distribute it to the electric motors on the cars where it is transformed into mechanical energy to give motion to the car.

The extensive development of the electric railway has given rise to numerous systems, which may be classified in several ways:

1. With respect to the current, as
   - *a*. Direct.
   - *b*. Alternating { single phase; three phase.
   - *c*. Combination alternating and direct.
2. With respect to the kind of power for current generation, as
   - *a*. Steam;
   - *b*. Hydraulic;
   - *c*. Gas engine.
3. With respect to the power system, as
   - *a*. Direct current transmission and distribution;
   - *b*. Alternating current transmission, direct current distribution;
   - *c*. Alternating current transmission and distribution.

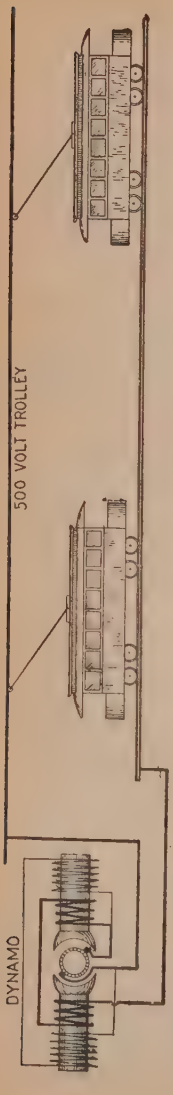


FIG. 6,103—*Direct current transmission and distribution.* The first system and the one most generany used in connection with city or short lines having a radius of 5 to 8 miles from the power house. The dynamo delivers current direct to the line at 550 volts, with the distribution system designed to deliver as nearly as possible 500 volts direct current at the motors on the cars. This system operates very satisfactorily and economically where the power is not transmitted further than mentioned above, but when it becomes necessary to extend the railway lines to greater distances into suburban districts and elsewhere, the excessive amount of copper required to transmit the power at the low voltage and maintain the proper voltage at the cars necessitates the use of *boosters* for increasing the voltage on the feeders in proportion to the demand, as shown in fig. 6,104.

4. With respect to the current collecting devices, as

a. Trolley;
b. Surface contact;
c. Third rail;
d. Conduit.

5. With respect to the location of the electrical source, as

a. External { power station.
b. On the car { storage battery; gas-electric plant.

6. With respect to the distribution pressure, as

a Low tension { pressures up to 600 volts.
b. High tension { pressures above 600 volts.

7. With respect to the service, as

a. City lines { elevated; surface; subway.
b. Interurban or suburban;
c. Long distance lines;
d. Industrial short lines.

Direct Current Transmission and Distribution.—This system is especially well adapted for densely populated sections

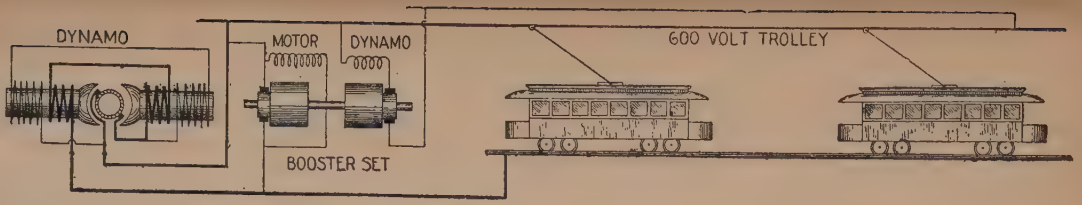


FIG. 6,104—Direct current transmission and distribution with booster. 650 volts at the dynamo, radius 7 to 15 miles from the power station. The booster, which consists, usually, of a series wound dynamo driven by an engine or a motor is connected directly in series with the feeder on which it is desired to raise the voltage. Its economy is due to the fact that the cost of the power for raising the voltage sufficiently to maintain the proper voltage at the end of the feeder is less than the interest charge on the larger amount of copper which would be required to accomplish the same result with the normal voltage loss of the system. The booster has the additional advantage, that in the case of a motor driven outfit, its loss varies substantially with the demand for current, whereas if copper were used, it would be necessary to employ a sufficient amount to take care of the maximum demand and still give normal voltage at the end of the line.

such as in large cities. It is also used on interurban and on a large percentage of the trunk line electrifications. The voltage used ranges from 500 to 3,000 volts. The lower voltage is not well adapted to the operation of roads covering large areas and is becoming obsolete, owing to the great amount of feeder copper required to transmit large amounts of energy at such low pressure.

Ques. Why is the use of boosters objectionable on these lines?

NOTE.—In addition to boosters of the motor generator type, as shown in fig. 6,104, some generating stations employ storage batteries to take care of peak loads and the sudden fluctuations of load characteristic of electric railway work. Batteries are used also in sub-stations at distant points on the system, where by means of reversible boosters, the battery is caused to take current from the power house feeder at a time when the power demand is low on the section supplied from the sub-station, thus storing up current which it subsequently delivers to the line when the power demand is heavy. In some cases the batteries are simply *floated* on the line and tend to equalize the demand and the voltage. By these means the radius of successful operation of direct current systems is extended to about 15 miles from the power house.

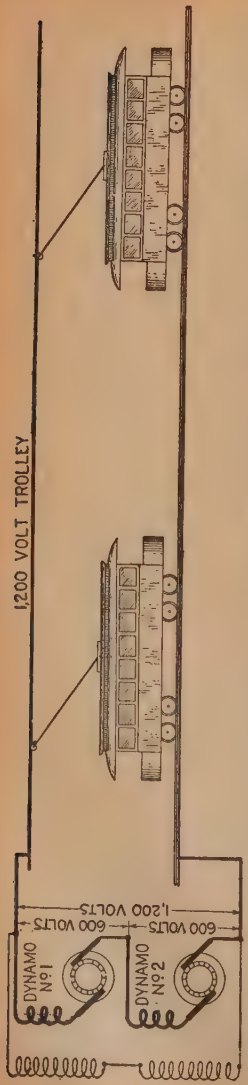


FIG. 6,105.—*Direct current transmission and distribution;* 1,200 volt two stage generation, radius 10 to 20 miles from the power station. *The generating plant consists of* two 600 volt dynamos operated normally in series, thus feeding into the trolley at 1,200 volts. Either 1,200 volt or 600 volt motors may be used; in the latter instance the motors are series connected in pairs. Most of the roads equipped with 1,200 volt apparatus have employed motors wound for 600 volts and insulated for 1,200 volts, two motors connected in series. When this arrangement is adopted with four motor equipments, the pairs are connected in series and parallel to give the excellent result obtained by series parallel control.

Ans. They add largely to the fuel expense.

A floating storage battery at the end of a long feeder is sometimes more expensive to install and operate than some of the other systems.

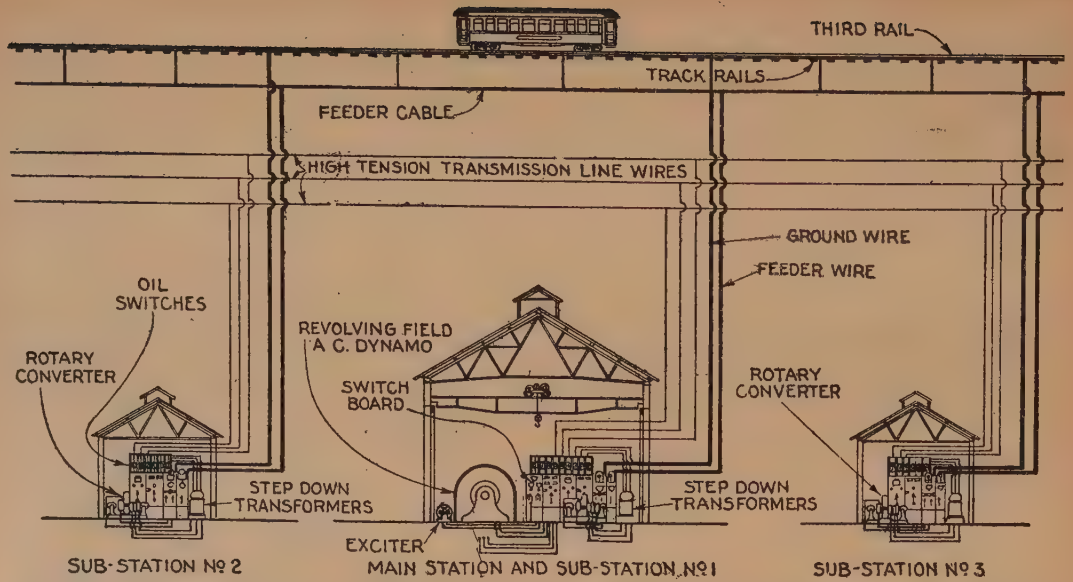
Ques. What are the standard voltages?

Ans. 600, 1,200, 1,500 and 2,400.

Ques. How are the motors operated at these various pressures?

Ans. The motors for the 600 volt system are designed for full trolley voltage. For the 1,200 volt system, both 1,200 volt and 600 volt motors are used, in the latter case, the motors are series connected in pairs. For the 2,400 volt system 1,200 volt motors are used, series connected in pairs.

Alternating Current Transmission, Direct Current Distribution. — The advantages accruing from the use of both *a.c.* and *d.c.* must be evident, thus, a



FIGS. 6,106 to 6,108.—*Alternating current transmission, direct current distribution.* The diagram shows the main station and two sub-stations with apparatus and connections to the line. In the system here shown three phase current is generated at the main station, where it passes to *step up* transformers to increase the pressure a suitable amount for economical transmission. At various points along the railway line are *sub-stations*, where the three phase current is reduced in pressure to 500 or 600 volts by *step down* transformers, and converted into direct current by rotary converters. The relatively low pressure direct current is then conveyed by *feeders* to the rails, resulting in a considerable saving in copper in moderate and long distance lines.

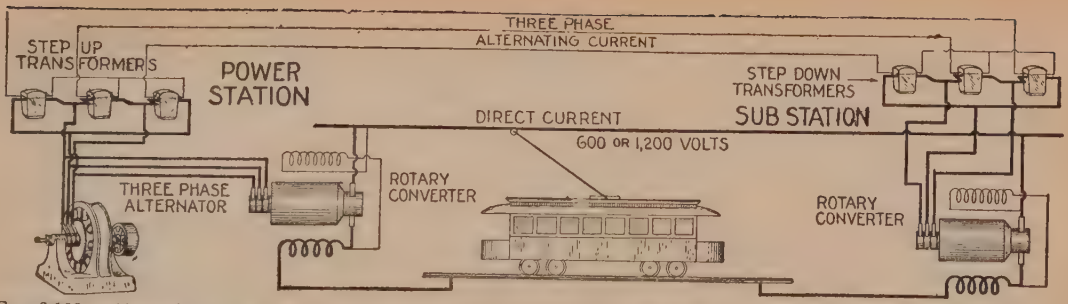


FIG. 6,109.—*Alternating current transmission, direct current distribution.* Sub-stations for 1,200 volt direct current trolley using two rotaries in series. Alternating current radius depends on the transmission voltage. ***The system shown consists of*** three phase 25 cycle alternator(s), wound for 360 to 390 volts, depending on the direct current voltage desired; step up transformers for raising the generated voltage to the voltage necessary for transmission; sub-stations each having one or more rotary converters, with each converter having a set of three step down transformers for lowering the alternating current voltage to the proper value for reception by the converter for conversion to the proper direct current voltage supplied by it to the trolley, and in some cases the installation of rotary converters in the power station, as shown, for taking current directly from the dynamos without transformation. In cases where a large amount of direct current is required near the power station, and for plants of moderate capacity where the transmission pressure is higher than 13,500 volts it is desirable to have the alternators wound for the low voltage stated; but for cases where the transmission voltage does not exceed 13,500 volts, the use of the step up transformer may be avoided by winding the alternators for the high voltage; while for cases where the units of power handled at the switchboard exceed 1,500 kilowatts it is almost essential that the generated voltage should be higher than 390 volts.

NOTE.—***The system*** shown in fig. 6,109 ***may be varied in several ways*** to satisfy special conditions, for example: 60 cycles may be used where the general lighting circuits are supplied from the same power house, and storage batteries may be installed in the sub-stations for equalizing the demand and reducing the rotary converter capacity necessary to take care of the load. The primary elements of all such installations are practically the same, however, and the sub-stations are usually placed from 10 to 15 miles apart, depending on the character of the road and the traffic.

large amount of power can be transmitted by alternating current at high voltage reducing the cost of copper to a minimum, and by means of rotary converters,

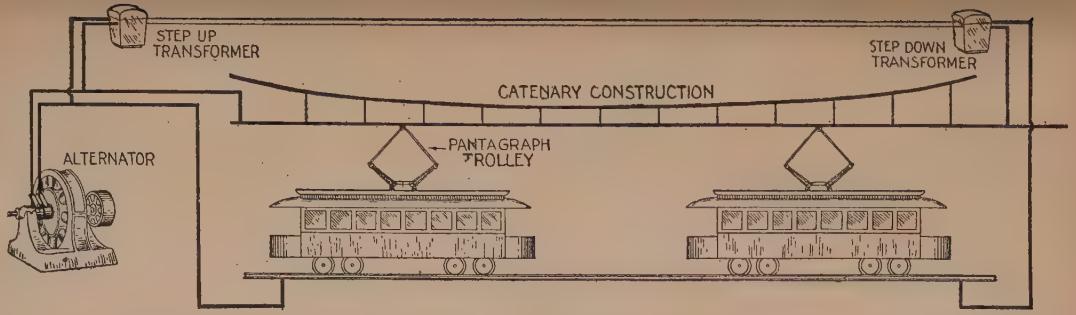


FIG. 6,110.—*Alternating current transmission and distribution.* For current suppiy a single phase alternator may be used, or one leg of a three phase machine. ***For short lines*** the alternator may be wound for the trolley voltage, but ***for long lines*** a high pressure machine must be used in connection with step down transformer sub-stations or a medium pressure machine with step up and step down transformer as here shown. A three phase alternator is used to advantage in cases where it is desirable to furnish polyphase current for stationary power service, one leg being used to furnish single phase current to the railway, and the two other legs to furnish current for the stationary service. Trolley voltages of 3,300, 6,600, 11,000, and as high as 13,000 are in use, but the usual pressure is 6,600 volts for ordinary trolley roads, and 11,000 for the electrification of existing steam railways.

converted into direct current of suitable working voltage for the motors at the distribution points.

Ques. Why is current generated at high voltage and then reduced to low voltage?

Ans. To cut down the cost of transmission.

Every additional car put on a line adds current consumption to that line, which means additional copper wire or cable needed. As the voltage or pressure has no bearing on the size of wire, but current or quantity (amperes) has, it can be transmitted at high voltage and low amperage, and then

FIG. 6,111.—Map of Staten Island, showing route of electrified section of the Rapid Transit Railway Company and generating station and sub-stations along the route.

converted to low voltage and high amperage at the points where needed, requiring only short cables of large size.

Alternating Current Transmission and Distribution.—Systems employing alternating current for both transmission and distribution, may be either

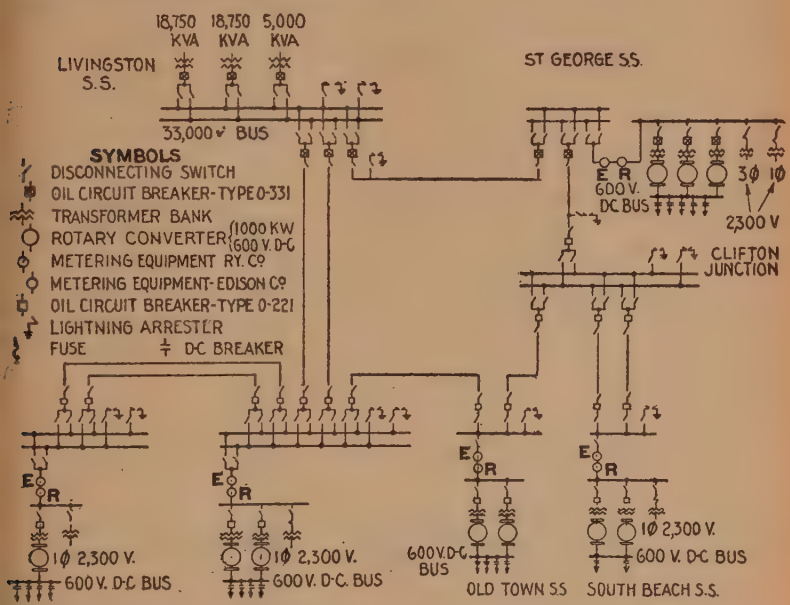
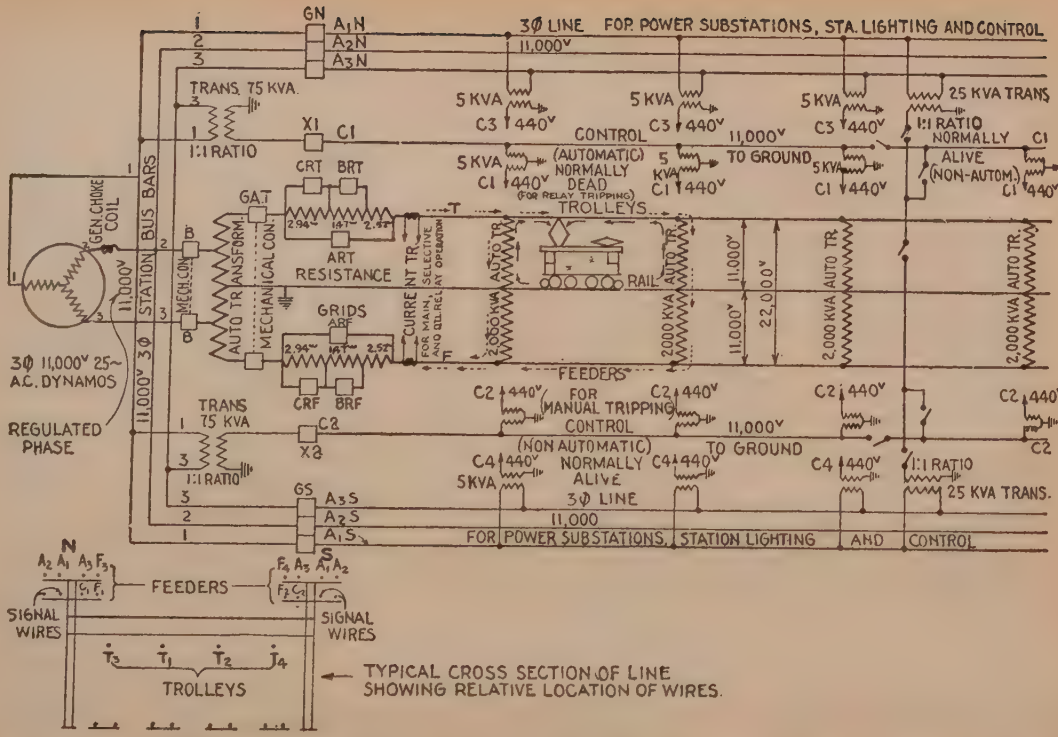


FIG. 6,112. Single line diagram of the 33,000 volt distribution system, Staten Island Railway, showing the distribution of the 33,000 volt power to the several sub-stations and the equipment it goes through for conversion to 600 volts direct current for the 3rd rails and trolleys.

1. Single phase, or
2. Three phase.

In the single phase system either series or modified repulsion, commutator type, single phase motors are used. Contact



FIGS. 6,113 and 6,114.—Schematic diagram of distribution system of New York, New Haven and Hartford Railroad, showing current limiting equipment, and auto-transformers on the electrified section. This is operated on a three wire system wherein

line voltages range from 3,300 to 25,000 volts. The contact line receives energy from transformer sub-stations located along the line. This system has been used only in interurban and trunk line service, the high contact line voltages being considered too dangerous for operation on city streets.

The alternators are usually wound for the trolley voltage and feed directly into the line without transformation, thus supplying the whole of the road. Where the length of the road exceeds 35 or 40 miles, it is equipped with step down transformers to lower the transmission voltage to that of the trolley. In cases where it is desirable to furnish polyphase current for stationary power service and for the operation of rotary converters, three phase alternators having one phase the full capacity are required, utilizing only one of the three phases for railway work. The cost of such installation does not differ materially from that of installations having single phase alternators.

In the three phase system the locomotives are equipped with three phase induction motors.

Two overhead contact lines are used, the track rails forming the third conductor of the three phase circuit.

FIGS. 6,113 and 6,114—*Text continued.*

the rails form the neutral between trolley and feeder circuits. The generation is at 11,000 volts; is stepped up to 22,000 volts for transmission, and trains operate on 11,000 volts by running between the trolley and the tracks which is one half the circuit. ***Wire symbols.***—A1-A2-A3, 3 ϕ line (AN, North 3 ϕ line) (AS, South 3 ϕ line); C1, automatic control line (for relay tripping of bridge circuit breakers); C2, non-automatic control line (for manual operation of bridge circuit breakers); C3 and C4, non-automatic control (for emergency operation of bridge circuit breakers). ***Circuit breaker symbols:*** ARF, ART, 1,500 amp. type "E" automatic (energized by selective and main relays); BRF, BRT, CRF, CRT, 300 amp. type "E" automatic; B, 1,200 amp. type "C" non-automatic; GA.F, GA.T, 1,500 amp. type "GA" automatic (energized by main and definite time limit relays); GN, GS, 600 amp. type "G" automatic; X1, X2, 300 amp. type "E" (X1 automatic X2, non-automatic); ***Operation sequence:*** (For short circuit on trolley side of line). 1, main and selective relays, energized by short; 2, selective ring trips ARF; 3, ART is opened; 4, BRF and BRT, open simultaneously and X1 closes; 5, CRF and CRT, open simultaneously and X1 closes; 6, X1, energizes tripping coils of bridge circuit breakers through relays affected by short; 7, if short is severe and persistent, D.T.L. relay trips, GA breakers, removing power from line. Steps 2, 3, 4 and 5, above, throw resistance in series with the line, cutting down the current flow. Selective relay always selects the "AR" circuit breaker on opposite side of line from short, for step 2, above.

Transformers on the locomotive are used to lower the contact line voltage to a value suitable for the motors where high contact line voltages are used, although for voltages up to 3,000 the transformers are often dispensed with. The contact lines receive their energy supply from transformer sub-stations, as in the single phase system.

While the great majority of railways now using electric motive power use either the direct current or the single phase systems, three phase locomotives with an aggregate rating of approximately 600,000 *k. p.* are in use at the present time, chiefly on the mountain grade railways of Italy.

Comparison of the Various Systems.—For ordinary street railway service the 600 volt direct current system is almost universally employed, but for interurban and trunk line service there is a great difference of opinion as to which of the various systems is the most economical when all the factors are taken into account. The factors which must be considered in comparing the three systems in any particular case are the following:

1. For a given weight and length of trolley or third rail the per cent. power loss for a given amount of power transmitted varies inversely as the square of the trolley or third rail voltage.

2. The higher the trolley or third rail voltage the fewer are the number of sub-stations required for the same efficiency of distribution and weight of conductor.

3. The higher the trolley or third rail voltage the more costly are the insulation and supporting structure, and also the greater is the cost of maintenance of the distribution system.

4. Both the first cost and annual expense of the sub-stations are less for the alternating current systems than for the direct current systems since, for the former, static transformers only are required, whereas, for the latter, rotary converters must be used.

5. The relatively low power factor of alternating current motors (80 to 90 per cent.) as well as the relatively low power factor of the line (due to the reactance of the trolley wire and track return) gives rise to a greater power loss in the alternating current distribution system for the same power delivered than in the case of the direct current system, and this great loss and lower power factor make necessary the employment of generating apparatus of greater kva. capacity.

6. The 600 volt direct current motor, for the same horse power rating and speed, costs less, weighs less, and occupies less space than either type of alternating current motor. The high voltage direct current motors cost more, weigh more, and occupy more space than the 600 volt type.

7. With the alternating current motors, transformers are required on the locomotives, which add to the cost and weight of the locomotive equipment.

8. The 600 volt direct current motor costs less to maintain and is liable to fewer operating troubles than any of the other motors.

9. With the commutating type of alternating current motor the power lost in the control equipment is practically negligible, since the pressure type of control can be used. For both the direct current motor and the induction motor a resistance control is necessary, with consequent loss in power.

10. The induction motor is inherently a constant speed machine, and consequently the power input varies directly as the opposing resistance. The direct current motor and the alternating current commutator motor are inherently variable speed machines, and the power input varies approximately as the square root of the opposing resistance, the speed at the same time falling off.

11. The three phase induction motor, when kept connected electrically to the source of power, automatically operates as an alternator when the train is going down grade at a speed greater than the synchronous speed of the motor, the motor thus returning power to the line and at the same time acting as a brake preventing any considerable increase in speed. *Regeneration*, as this action is called, can also be obtained with the other types of motor, but only at increased expense for the additional control equipment required.

Comparison of Current Collecting Devices.—The various methods of collecting current from the line wire are due to experience with different operating conditions. Each has features especially suited for the conditions under which it is to work.

The overhead trolley system is largely used in towns and cities.

The surface contact system may be advantageously used in some industrial works where an overhead trolley is objectionable, and a third rail is not permissible.

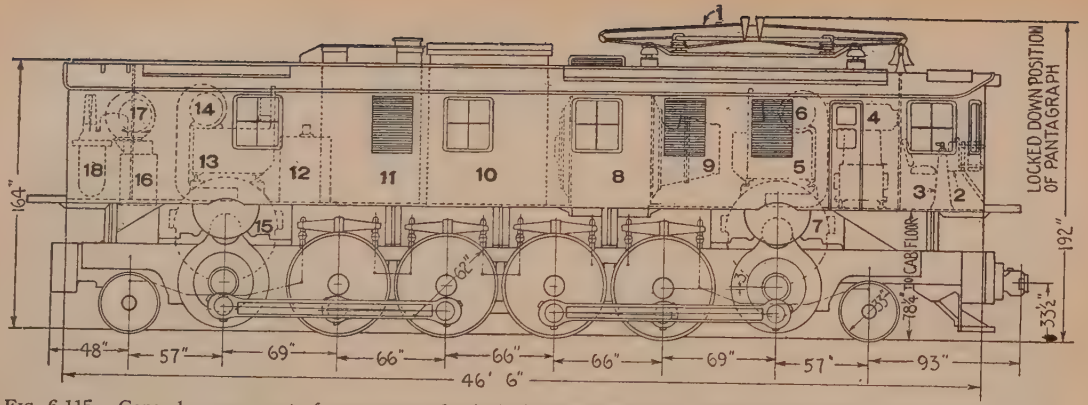


FIG. 6,115.—General arrangement of apparatus and principal dimensions of the Virginian locomotives. They are of the split phase, constant speed type with one three phase induction motor driving, through a jack shaft and side rods, two of the driving axles in each truck. Single phase, 25 cycle power at a pressure of either 11,000 or 22,000 volts is supplied to the transformer on the locomotive through a pantagraph collector. Low voltage power for the three phase traction motors and for the auxiliaries is taken from the transformer and phase converter. The traction motors are of the induction type arranged for two comparatively constant running speeds of 14 and 28 *m.p.h.* ***The parts are:*** 1, pantagraph; 2, master controller; 3, air brake valve pedestal; 4, air compressor; 5, control apparatus on traction motor; 6, traction motor blowers; 7, traction motor; 8, phase converter; 9, phase converter starting motor; 10, liquid rheostat; 11, main transformer; 12, preventive coil; 13, control apparatus on traction motor; 14, traction motor blower; 15, traction motor; 16, transformer oil cooling radiator; 17, radiator blower; 18, oil circuit breaker.

As this system can be used without poles or overhead wires, it leaves yards and buildings free from all obstructions.

The third rail system is extensively used on elevated railways, subway systems and on those roads which have a private right of way, as in the case of electrified steam roads, which operate heavy trains at high speed.

By means of the third rail it is possible to successfully deliver to the cars much heavier currents, and to operate the cars safely at higher speeds than is possible with the ordinary type of overhead or underground trolley construction, two important features which serve to greatly expand the field of application of the 500 volt direct current motor.

The underground trolley or conduit system is used in the streets of large cities where the use of overhead trolley wires is objectionable, but the cost of construction is very great.

The underground trolley system differs from the overhead trolley in that it has a metallic circuit (two insulated conductors) while the overhead trolley has a ground return, that is to say, the track rails which are not insulated from the ground are used as the return.

Source of Power.—On main lines the current is generated in a power station and fed direct to the line at various points or to sub-stations where it is stepped down to the proper voltage for distribution to the lines. However, on branch lines having light traffic it has been found more economical to employ separate power units on the car, this system being known as gas electric drive is fully described in another chapter.

Single Phase System.—Almost since the early days of light electric traction, the problem of heavy electric traction has been given much thought. In the earlier considerations, the principal difficulty was supposed to lie in the ability of the manufacturers to produce sufficiently powerful equipment. However, it was not long before more serious difficulties presented themselves and some of these are with us even to the present day.

With direct current generation and distribution for 550 to 600 volts which was the accepted standard, railway engineers were confronted with the problem of transmitting large units of power for considerable distances.

FIG. 6,116.—Two Baldwin-Westinghouse single phase motor generator type locomotives in service on the Great Northern Railway.

This meant closely spaced power supply stations and, with direct current generation, this implied subdivision of the power supply into a number of separate units, which was in opposition to the growing tendency to concentrate the power generation into large central stations. In other words, this was in the direction of subdivision instead of centralization.

A second serious difficulty was in supplying this power to a moving locomotive or train.

With low voltage and large power the collection and handling of the current was then, and still is, a serious problem.

With these two conditions encountered, heavy railway electrification was practically at a standstill, and, in the minds of those who knew, there seemed but little promise for future railway electrification on a large scale.

It is true that a number of attempts were made to build electric locomotives in the early days, but these were mostly by those who were familiar with the traction problem only and who had but little or no experience with the generation and transmission problems.

The rotary converter presented a solution of one of the difficulties for by means of polyphase *a.c.* generation and distribution at high voltage, and conversion to *d.c.* through distributed sub-stations, the problem of centralization of the power stations was accomplished. However, the problem of collection and handling of the low voltage current was still to be met, so that the rotary converter only partially solved the heavy railway problem.

Another step, however, represented a very material advance, namely, the development of the third rail.

This permitted relatively high amounts of current to be transmitted from the sub-station to the moving vehicles, and thus it appeared, for a while, to solve the second part of the heavy railway problem. In consequence, after the development of the rotary converter and the advent of the third rail, the heavier work went forward by leaps and bounds. However, it may be noted that this was only where traffic was very heavy, such as for elevated and subway service in the larger cities, for city terminals, suburban railway service, etc.

As soon as application of the third rail and the rotary converter system began to be considered in connection with longer lines, with infrequent service, the limitations of this arrangement began to be apparent, these being largely of a financial nature.

In other words, while it would be possible, from an engineering standpoint, to build and operate successfully a long main line railway by means of rotary converters and the 600 volt third rail system, yet the figures showed most positively that the first cost and the operating expense would render such an arrangement unprofitable. Thus, the rotary converter and third rail solution of the problem was not a general one and applied only to isolated cases where the traffic was very heavy and the service very frequent, or where there was some serious limitation to the use of steam, necessitating either the abandonment of the steam locomotive altogether, or an excessive expense in some form due to its retention.

The well known Zossen experiments in Germany with a three phase, high voltage trolley system, with induction motors, attracted a great deal of attention, all out of proportion to the true value of the results.

This was a very spectacular undertaking and indirectly had a bearing on the future railway work.

High Voltage Necessary for Heavy Electric Traction.—Owing to the amount of energy required in heavy traction, obviously a high voltage is necessary to reduce the amount of current required and in turn the amount of copper. With *a.c.* it was easy enough to meet the high voltage, but there were other limitations.

In the three phase traction system, as brought out by the Ganz Company in Europe, three phase motors of large power could be used, but there was the handicap of two overhead wires at different voltages, thus involving a double collection of current.

Moreover, this system was apparently limited to about 3,000 or 4,000 volts and if one were to use *a. c.* at all, there should be no such limitation in the voltage. Furthermore, for lighter service, involving relatively small motors, the polyphase induction motor did not seem to furnish a very satisfactory solution of the traction problem.

Direct current was recognized, even at this time, as a possible solution, provided very materially higher voltages than 600 could be used, but almost everybody had doubts as to the practicability of sufficiently high voltage, either on the dynamos or on the motor equipment. Thus much thought was given to the possibilities of single phase, alternating current, for here one could use the single overhead trolley with the voltage limitations very largely removed. However, engineers were faced by the fact that there was as yet no suitable single phase motor available.

FIG. 6,117.—Westinghouse equipped, single phase, 215 ton motive power units as used on Virginian Railway.

Experiments resulted in a series type single phase motor with commutator, resembling in characteristics the series type direct current motor. It had been recognized for years that the variable speed characteristics of the series type motor were ideal for traction service and thus in attempting this new solution of the railway problem, engineers attempted to retain the fundamental characteristics of the existing *d.c.* system.

The single phase commutator type railway motor, although it is not as economical or efficient as the *d.c.* motor, has the

advantages of simplicity and economy of the transmission system, together with the more economical speed control.

From the speed control standpoint, the single phase system was far ahead of the direct current, for the flexibility of the alternating current system allowed voltage variations for controlling the motor speed, without the use of regulating rheostats for absorbing the extra voltage and power. Here was considered one of the major advantages, especially for locomotive work.

Within a few years it developed that the single phase system was not a satisfactory alternative to the existing direct current system in general, but that it had its own field, and this field was where the special characteristics and advantages of high trolley voltages would apply. In other words, the single phase system really began where the existing direct current system was handicapped by trolley limitations.

While there were at first some misapplications of the single phase system, due largely to over enthusiasm, yet within a very few years it began to be applied to heavy service and in all such installations it has persisted, and not only persisted, but has enlarged its field. One of the first systems to adopt this was the St. Clair Tunnel under the Detroit River, which was initiated about 1906. This electrification was necessitated on account of the smoke problem. The equipment consisted entirely of slow speed locomotives and the first locomotives installed are still in use with a most remarkable record of reliability and low maintenance cost.

One of the principal requirements of this system was that any locomotive must come up against its load with full load, or even overload torque for a period as long as five minutes. At that time, this was a prohibitive condition for the single phase commutator type motor, and, therefore, the three phase

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NOTE — The Norfolk and Western Railroad uses three phase motors. In electrifying its Road, the Norfolk and Western system on the mountain grades in West Virginia encountered the problem of operating heavy trains on a steep grade and having them driven at the other side by other words, to some extent, it necessitated a hoisting problem. There were certain conditions presented from the operating standpoint which seemed to be met better by the induction motor than by any other type. However, the induction motor would not operate from the single phase contact line and the commutator system was not satisfactory on account of the comparatively low rail bonding and the difficulties of high voltage. Consequently, a modification of the single phase system was used in which single phase current was supplied to the locomotive and was there converted to polyphase current by means of a "phase splitter" or "phase converter."

seemed to be the most practicable solution. The Norfolk and Western installation, therefore, simply represents one of the modifications of the single phase system in general.

Subsequent orders for locomotives for the Norfolk and Western were filled with locomotive equipments more powerful than the original and with improved auxiliary equipment. This has resulted in an improvement in the line power factor and in consequence an improved regulation of trolley voltage is obtained.

TEST QUESTIONS

1. *Give classification of electric railway systems.*
2. *Why are boosters objectionable on* d.c. *transmission and distribution systems?*
3. *What are the standard* d.c. *voltages?*
4. *Why is current used at low voltage on* d.c. *systems?*
5. *What type motors are used for single phase systems?*
6. *Give a comparison of the various systems.*
7. *Where is the overhead trolley system largely used?*
8. *For what service is the third rail system especially adapted?*
9. *Where is the underground trolley used?*
10. *Where is the current generated for main lines?*
11. *How is the current obtained for branch lines?*
12. *For what service is high voltage necessary and why?*
13. *Why is high voltage objectionable on commutator motors?*

14. *Is a single phase commutator motor as efficient as a* d.c. *motor?*
15. *What advantages has the single phase system over the* d.c. *system?*
16. *What kind of motors are used on the Norfolk and Western Railway electrification?*

CHAPTER 131

Gas Electric Bus Drive

During the last ten years there has been a rapidly growing demand for some flexible means of transportation to handle traffic which lies away from established routes or which has become too great for the existing systems. The satisfactory manner in which the motor bus is meeting this demand is shown by the fact that in this period the number of motor buses in transportation service in the United States has grown from almost nothing to approximately 95,000. This comparatively new type of vehicle is being used extensively, not only to form new systems, but also to extend systems that have been in operation for many years.

From the time when motor buses were introduced into the transportation field, operators have been confronted with the problem of finding a flexible and automatic means of converting the constant torque of the gasoline engine into speed and tractive effort at the rear wheels. Many difficulties were experienced with the use of the conventional transmission gears and clutch.

Comparison of Gear Shift and Electric Drive.—With the gear shift, the time lost in gear shifting as compared with the quick acceleration of the electric motor, is appreciable. Moreover, during this time, the gasoline engine is doing no useful work. A third objectionable feature of the gear shift is that

the uneven application of power due to gear shifting causes excessive strains in all parts of the vehicle. This shortens the life of the entire coach; increases the maintenance costs and lastly the uneven acceleration adds to the discomfort of the passengers.

The gas electric bus drive is *a substitute for the clutch, transmission and differential of the gas direct drive.* As already explained, this substitution is to obtain rapid and even acceleration and flexibility.

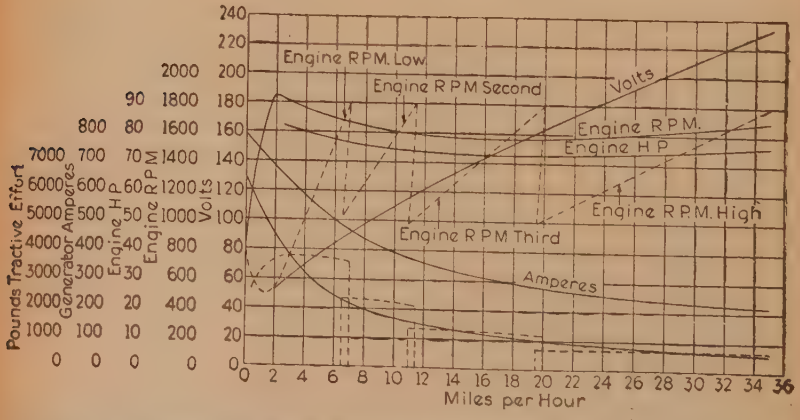


FIG. 6,118.—Comparison of characteristics of gas electric and mechanical drives. The curves show engine characteristics and tractive effort at the rim of the wheels, obtained with a typical gas electric drive application, compared with that of a mechanical drive bus equipped with a prime mover of the same capacity.

Gas Electric Power Plant.—The gas electric drive consists of *gas engine, dynamo, controller and one or more motors.*

With this outfit, the operator has no clutch to pedal, and has no gears to shift, but obtains acceleration merely by depressing a pedal; this is of importance to him because it vitally affects the two most costly phases of operating expense, namely, labor costs and accidents. These advantages

offset the additional fuel which may be necessary to carry the additional weight of the electrical apparatus.

A gain in rapidity of acceleration means a gain in speed, and a gain in speed means a reduction in the cost of wages per mile, due to getting more miles for an hour of driver's time.

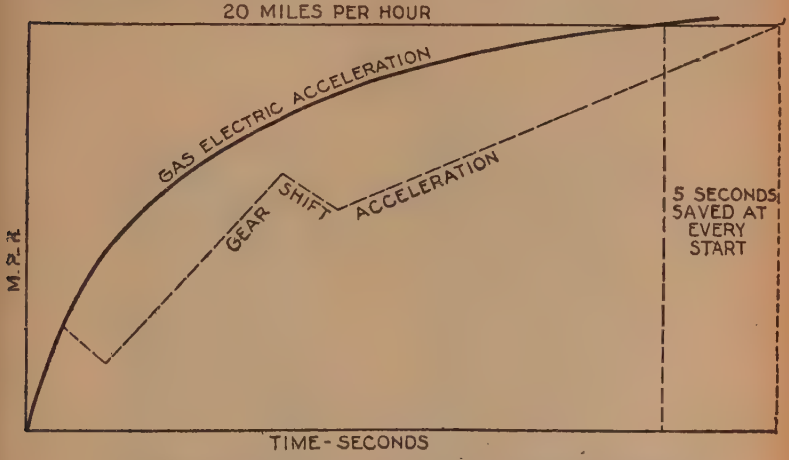


FIG. 6,119.—Comparative acceleration curves for gas electric and gear shift drives.

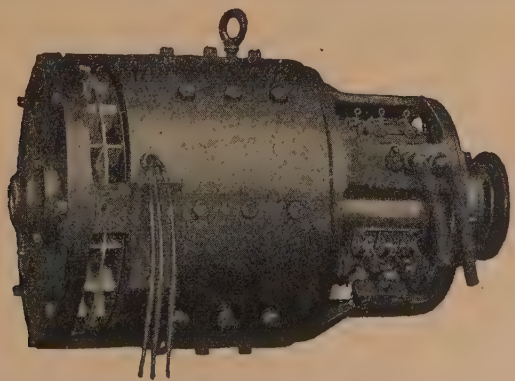
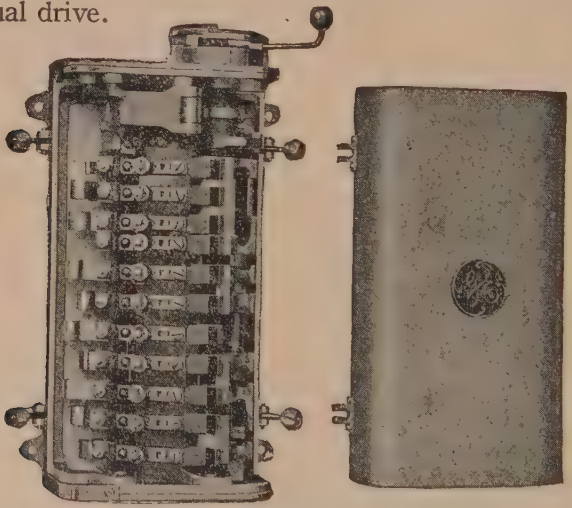


FIG. 6,120.—General Electric dynamo for gas electric drive: covers removed.

The vehicle with the electric drive starts off and continues up to its crest speed with a gradually increasing torque, and without at any time putting a severe strain on any part of the mechanism. This is the nearest approach to the flexibility of steam power.

There are two types of drive in general use, classed as

1. Single motor drive;
2. Dual drive.



FIGS. 6,121 and 6,122.—General Electric controller for double motor gas electric drive.

The advantages of these two types are as follows:

Single Motor Drive

1. The equipment is lighter in weight and has a lower first cost.
2. It permits the use of standard rear axles.
3. Any chassis can be more readily adapted to electric drive of this type.

Dual Drive

1. The differential is eliminated, thus reducing the chance of wheel slippage and skidding.
2. Better clearance is afforded below the motors for a given floor height.
3. Operation with one motor is possible in emergencies.

Fig. 6,124 shows assembly of chassis and power plant of the single motor type, and fig. 6,125 the double drive type. Other details are shown in the accompanying illustrations.

Maintenance of Gasoline-Electric Buses.—Although gas electric drive eliminates those destructive forces which characterize the ordinary mechanical drive, regular inspection and thorough periodic overhauling are necessary for satisfactory operation. An important test is the engine test.

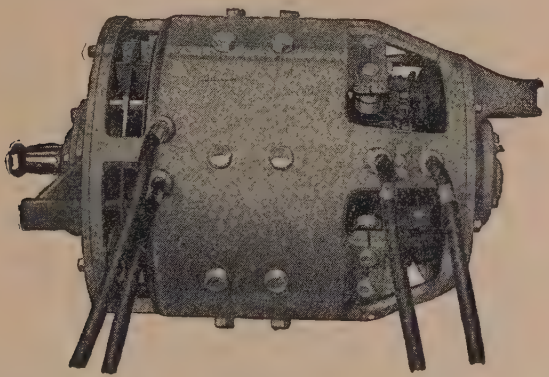


FIG. 6,123.—General Electric motor for gas electric double motor drive.

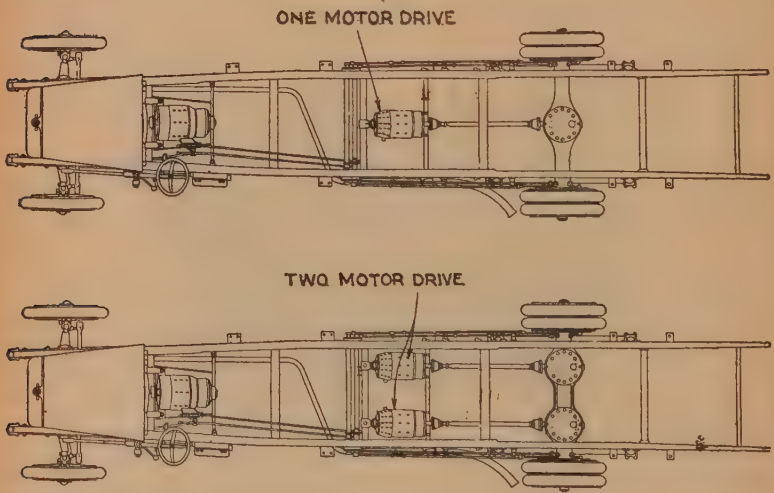
To make this test, connect the dynamo with a water rheostat, and read the meter,—volts and amperes, at various speeds. Compare with the original test chart which provides a definite indication of the power plant's condition. The effect of every change or adjustment is immediately visible in electric output.

A further check will be made by keeping an accurate record of the gas consumption for each bus.

When a bus shows a reduced number of *kw.* hours per gallon of gasoline it is a definite indication that the engine or dynamo should be inspected.

1,000 Mile Inspection.—After each 1,000 miles of service each part of the vehicle should be inspected, and all wheel bearings and wearing parts lubricated.

The commutators of dynamos and motors should be tested for loose bars or high mica, the brushes checked for wear and free movement in the brush-holder.



FIGS. 6,124 and 6,125.—Bus chassis with single motor gas electric drive and with double motor gas electric drive.

Controller, relay and accelerator switch should be inspected for burned contact fingers and the necessary adjustment made. The braking resistor should be checked for broken grids.

This entire inspection should take from two to four man-hours, of which time one-half hour of this time should be devoted to the electrical equipment.

2,000 Mile Inspection.—The 2,000 mile inspection should cover a more rigid survey of the mechanical portions of the vehicle with the viewpoint of replacing abnormally worn or

defective parts. In addition to the oiling and greasing done at 1,000 miles, the oil in the engine crank case should be changed.

At this time the electrical equipment should be inspected as at 1,000 miles and in addition dynamos and motors should be inspected for proper brush spring tension. Any road dirt or dust that has collected inside the machines should be blown out with dry compressed air and bearings checked for noise.

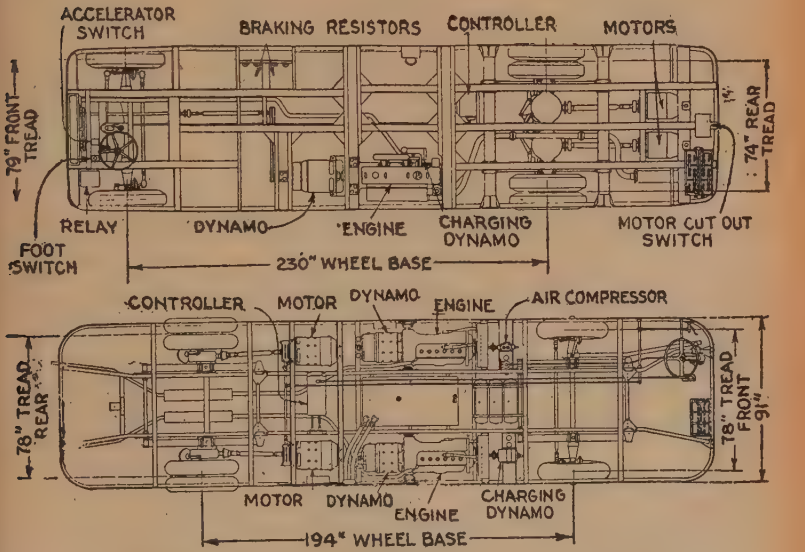


FIG. 6,126.—Equipment layout of 40 passenger single power plant gas electric coach.

FIG. 6,127.—Equipment layout of 40 passenger dual power plant, gas electric coach.

The controller, relay and accelerator switch finger pressure should be checked and adjusted if necessary.

The complete inspection should take from five to seven man-hours. Approximately one hour should be spent on the electrical equipment.

30,000 Mile Inspection.—After 30,000 miles of service it has been found economical to include certain maintenance work on the vehicle in addition to the regular inspections previously outlined. This work is usually done in the regular

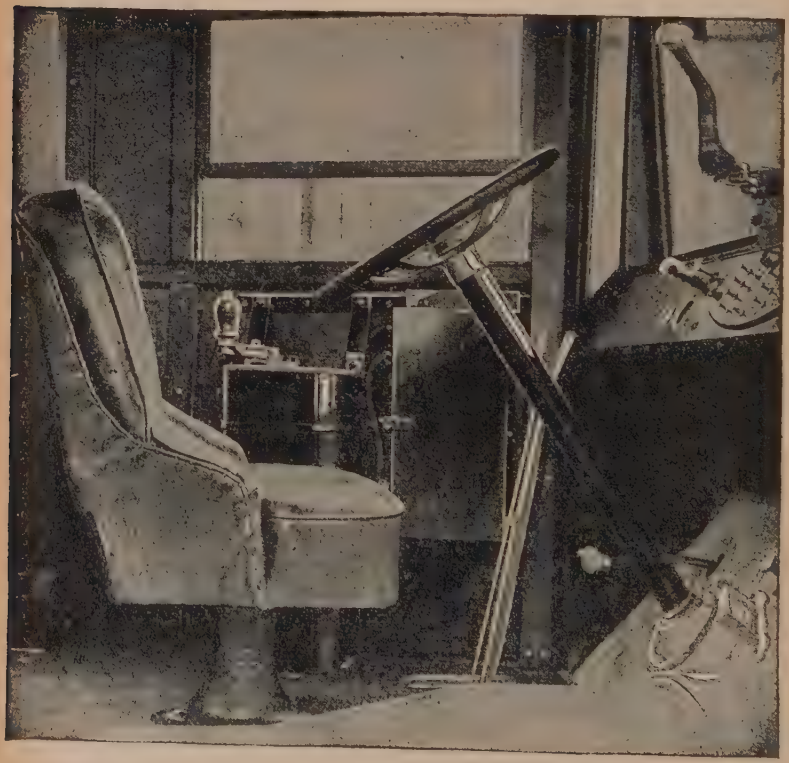


FIG. 6,128.—Interior view of General Electric gas electric drive bus showing dash and control. In addition to the regular pedal operated service brake and a hand lever emergency brake, this drive has an electric brake operated by a controller handle. On long, steep grades this method saves wear on brake bands and provides a positive uniform retarding force against which the bus cannot get out of control. It is also available as an emergency brake under any operating condition.

inspection garage although the electrical units are not usually removed from the chassis. At this time the gasoline engine is completely overhauled and other mechanical portions of the chassis are checked for wear and replaced if necessary.

In addition to repeating the work done on the electrical equipment at the 1,000 and 2,000 mile inspections, it may be found necessary in the case of the earlier types of equipment, to remove the dynamos from the chassis and turn down and under cut the commutators.

This inspection should take from ten to twelve man-hours, about two hours of which should be spent on the electrical equipment.

Unit Overhaul Periods.—In addition to the regular inspection periods outlined, it is almost universal practice among gasoline electric motor bus operators to establish a regular unit overhaul period at which time each individual unit is disassembled, checked for wear and repaired or renewed if necessary.

The length of service between these overhaul periods varies with the class of operation, but a good average figure is 100,000 miles. At this time all electrical units should be removed from the chassis.

Motors and dynamos should be completely disassembled and each part thoroughly cleaned. All armatures and field coils should be dipped in a good insulating varnish and thoroughly baked. The commutator should be tightened, turned down and undercut. Ball bearings on all electrical machines should be checked for worn or cracked balls, and replaced if defective. Brush holder boxes should be checked for wear.

Before reassembling the dynamo and motors each individual part should be given a high voltage test of twice the normal voltage and after assembling, each complete machine should be given a similar high voltage test. The main controller should be thoroughly cleaned and all burned spots on the drum should be dressed with a fine file. Fingers that show signs of heating or burning should be replaced. When work is completed on the controller it should be given the high voltage test recommended for the armatures. The contacts, fingers, and springs of the relay and accelerator switch should be replaced. The braking resistors should be checked for broken grids and given the high potential test recommended for the motors and dynamos.

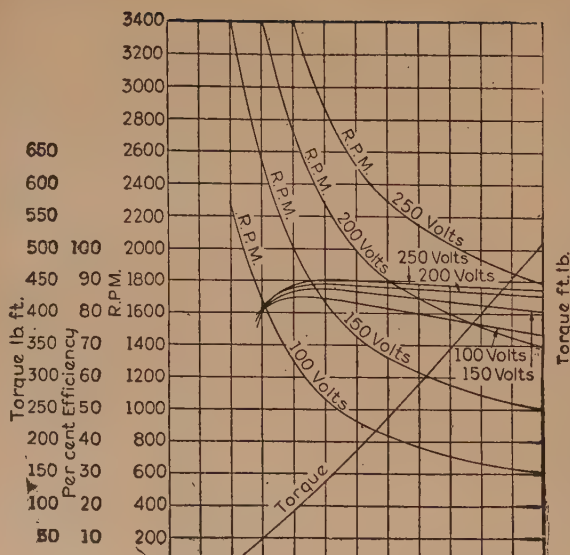
This entire procedure so far as the electrical equipment is concerned should consume from 20 to 30 man-hours. The time taken for doing all of the overhaul work is approximately eight working days.

After the vehicle has been overhauled it should be in first class condition for another 100,000 miles of service with the intervening inspection periods as above outlined. The question of body painting has purposely been excluded as this item is subject to the desires of the particular operator involved. The number of men necessary to carry out the inspection and maintenance schedule outlined will, of course, depend on the garage facilities available and the number of vehicles operated.

A survey of the operation of 1,400 gasoline electric motor buses covering a number of properties of different sizes has shown that 3.5 vehicles per garage employee is a fairly good average figure for carrying out this work. This includes garage foremen and assistants, mechanics and helpers, electricians and helpers, carpenters, gassers and oilers, greasers and stock room employees. An attempt was made during this survey to determine the ratio of electricians per vehicle operated, but it was found that this was impossible due to the variation in the system of rating employees used by different carriers.

TEST QUESTIONS

1. *What is understood by the term "gas electric drive" for buses?*
2. *Give a comparison of gear shift and electric drive.*
3. *For what is the gas electric bus drive a substitute?*
4. *Of what does the gas electric power plant consist?*
5. *Is acceleration quicker with the gas electric drive than with the gear shift drive?*



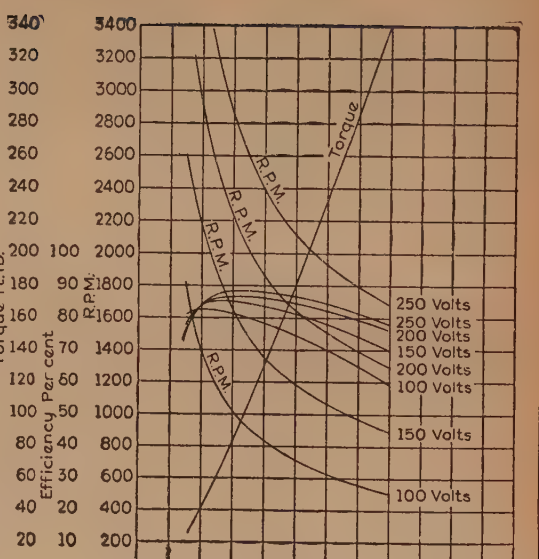


FIG. 6,129.—Characteristic curves of General Electric single motor for gas electric drive.

FIG. 6,130.—Characteristic curves of General Electric double motor for gas electric drive.

6. *What two types of gas electric drive are in general use?*
7. *Give a comparison of the two types of gas electric drive.*
8. *How is the engine test made of a gas electric power plant?*
9. *When a bus shows a reduced number of* kw. *hours per gallon of gasoline, what does it indicate?*
10. *Describe the* 1,000 *mile inspection.*
11. *What should the* 2,000 *mile inspection cover?*
12. *How much time is required for a* 2,000 *mile inspection?*
13. *What should be included in a* 30,000 *mile inspection?*
14. *When should a unit overhaul be made?*
15. *Describe fully what should be done in a unit overhaul.*

CHAPTER 132

Gas Electric Railway Cars

One of the most difficult problems facing the railroads is the operation of the light traffic and branch line trains. With modern highways paralleling the railroads throughout the country, the competition of automobiles, motor buses, and trucks has resulted in a heavy loss of business. This is a problem which requires a double solution; first, the reduction of operating costs; second, the increase of revenue from passenger and freight traffic.

The principal operating costs, wages, fuel, maintenance and terminal expenses, cannot be reduced materially with steam operation; nor is it profitable to replace the old rolling stock with new, modern cars to attract passengers.

The solution of the problem lies in the operation of gas electric railway cars.

Many railroads have decided on this form of transportation and have inaugurated programs for a complete adoption of these cars for light traffic service. It has been demonstrated that operating and maintenance costs are materially decreased because of lower cost of fuel, reduced engine and train crews, increased availability and simplicity of the entire equipment. It has also been found that passengers are attracted by the cleanliness and smooth riding qualities of this type of car.

Gas electric cars are in service in all parts of the country and are handling light traffic runs with mileage up to 400 miles per day.

They are operated usually in two car trains, handling a light passenger or combination baggage car. The engine equipment varies in horse power from 135 to 400, and some cars have two engines. The power available in such cases varies from 240 to 800 *h.p.*

FIG. 6,131.—General Electric all passenger gas electric railway car used on the Maryland and Pennsylvania Railroad.

General Description.—Gas electric railway cars are made for all types of service. They range from the 75 foot car with engine, postal, express, baggage, smoking and passenger compartments, to the 40 foot power unit with larger engines and small baggage space, as well as lighter cars with small power

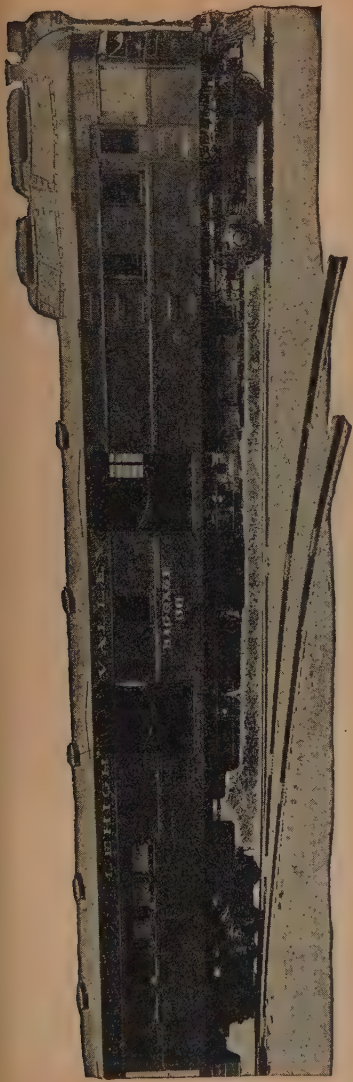


Fig. 6,132.—General Electric combination car with baggage and passenger compartments.

units for special light service. Most of these cars have an installed engine capacity ranging from 200 to 800 horse power.

The service handled in the majority of cases requires a motor car and a 35 ton trail car, which is usually a light passenger, baggage, or combination car.

Many standard sizes of power plant equipment, ranging from 135 to 800 horse power are available.

Some railroads prefer a single, large engine unit, whereas others prefer two smaller equipments in one car. Many cars have two large engine units for heavy service. The most popular, however, is the 275 horse power car.

The larger cars handle several coaches, depending upon the character of the service and the profile of the road. The trend is toward larger engines and equipments. The single car train, with a 225 horse power engine equipment, weighs approximately 42 tons with an average load of passengers and baggage.

A two car train with a 35 ton trailer weighs approximately 77 tons. Cars with 275 horse power engines have an average weight of 50 tons, and with a 35 ton trailer, can handle heavier schedules than a smaller car. The usual gear ratio recommended for this class of service is suitable for operation at a maximum car speed of 60 miles per hour under full power. Gear ratios may be selected from special service and train weight to meet local conditions of tonnage and grade.

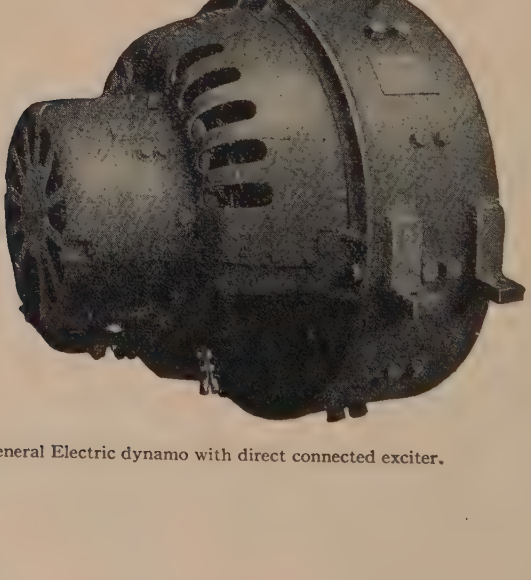


FIG. 6,133.—General Electric dynamo with direct connected exciter.

NOTE.—***The gas electric car*** is considered by some to be a piece of electrical equipment with an incidental engine and car body, by others as an engine with an incidental car body and electric transmission equipment, and still by others as a car with an incidental motive power equipment. These points of view are taken by the several contributing manufacturers of the gas electric motor car. Some railroad operators have tried to assemble parts from different concerns into an old railroad coach and have it operate successfully as a rail car. These people can testify as to the importance of purchasing a finished motor car in which all the various functions have been properly engineered into the finished product. It is difficult to take an engine, dynamo and traction motor without careful study and engineering knowledge and make them work properly and economically in a smooth and reliable manner. Recent years have resulted not only in the development of modern rail cars, but in the development of recognized expert motor car builders.

Some builders have adopted crosswise mounting of the power plant as standard.

This requires an engine room approximately 8 feet long for a single unit and 14 feet for a double unit power plant. Other car builders install the engine lengthwise in a compartment 12 feet to 14 feet long.

The weights of the motor car trains vary from 30 tons for one car to 195

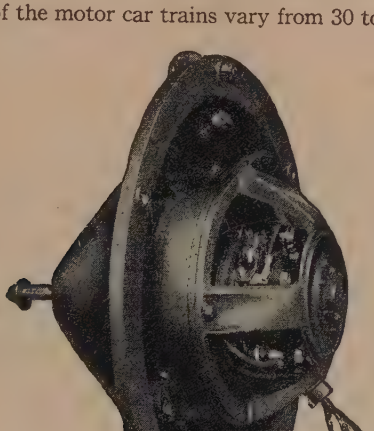


FIG. 6,134.—General Electric radiator fan motor equipped for vertical or horizontal mounting. Many car builders require a forced ventilated engine radiator to maintain proper cooling water temperatures. The motor is controlled by the motor car engine man, and turned on and off in accordance with the water temperature gauge on the engine.

tons for three or four cars. The car horse power varies under these conditions from 135 to 800, with a corresponding horse power per ton of from 5.35 to 3.14.

Engines.—Electric transmission equipments are used with engines which have been designed especially for railway use. These engines operate at moderate speeds with economical fuel consumption and are easily maintained at a minimum cost.

The engines are usually started from a storage battery by means of a series winding on the dynamo. A few use a starting motor and a ring gear on the fly wheel, while many have the additional feature of compressed air starting from the air brake system through a distributing valve on the engine.

Dynamos.—These are designed to give full engine output consistent with minimum size and weight throughout the operating range of the car. A typical dynamo is shown in fig. 6,133

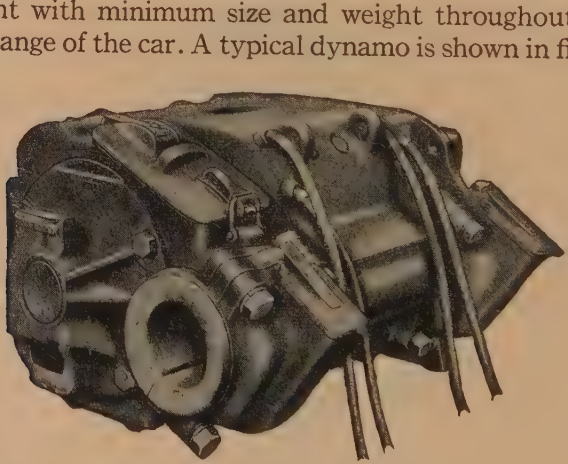


FIG. 6,135.—General Electric truck mounted driving motor, axle side.

The engine builder usually supplies the flexible coupling between the engine and dynamo. This coupling absorbs the harmonic vibrations of the crank shaft, and protects the set from stresses caused by slight misalignment.

The dynamo conforms to the requirements of standard railway service in construction, insulation, finish of parts, and bolt fastenings. The dynamo is so designed that it has a characteristic which is inherent and gives an output curve which automatically follows that of the engine throughout the normal operating range of the car. This characteristic, combined with the governor characteristic of the engine, results in the maximum utilization of power and in the operation of the engine at its normal capacity with the least possible complication of equipment.

Power for the dynamo field is supplied by a direct connected exciter, the magnet frame of which is supported on the dynamo bearing bracket.

Motors.—The driving motors, shown in figs. 6,135 and 6,136, are carried on the car truck and connected to the axle by spur gearing in accordance with well established practice. One side of the motor is carried by the car axle, and the other is supported on the truck transom by a spring nose suspension. This method of support reduces vibration and shock to the

FIG. 6,136.—General Electric truck mounted driving motor, suspension side.

motors, caused by switches, frogs and irregularities in the tracks. This is particularly important on branch lines where the track is often less carefully maintained than on the main line.

The motors have a high output consistent with light weight, and are capable of operation under the varying characteristic of the dynamo power. Among the most popular of these motors are the 150 horse power for cars up to 300 horse power and the 220 horse power motor for the larger cars. They are particularly designed to match the dynamo characteristics and to give the best efficiency. Reduced field operation of the motor is provided at the higher car speeds. This method of operation is necessary in order to obtain the greater outputs at the higher speeds and still retain the compact design.

Control Equipment.—For gas electric cars, control equipment consists of a switch gear and cable through which power is supplied from the dynamo to the motors. It provides a

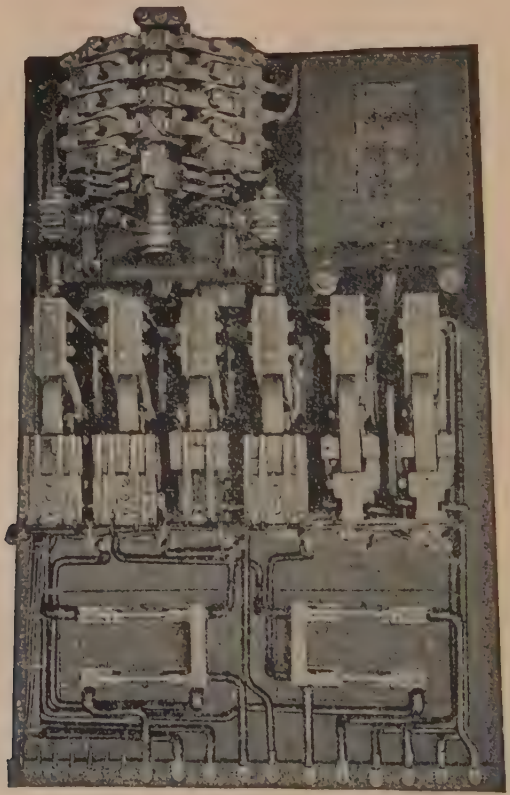


FIG. 6,137.—General Electric high voltage remote contactor control. This equipment includes a master controller with contactor and reverser panels, as well as the auxiliary switches and battery charging equipment. Remote contactor control is well adapted to double power plant and double equipment. The pneumatic type of remote control is actuated by air from the brake system with magnetic valves operated from the master controller. The magnetic type of control consists of the usual contactors, which are operated directly from the master controller.

means of connecting the motors in series and parallel combinations for the best car operation.

This control is not to be confused with the differential field control of the dynamo, which is inherent and regulates the power output.

Either direct drum control or remote contactor control may be used.

FIG. 6,138.—General Electric master controller for remote control.

FIG. 6,139.—General Electric direct drum controller.

The drum type control is the simpler of the two and consists of a controller which makes all of the required connections between the dynamo and the motor.

This controller is manually and positively operated. The wire, cable, auxiliary switches, and small battery panel complete the equipment. Drum

type control is an extremely popular type and is used on the majority of cars. It is employed with all sizes of units.

The remote type of control has been designed for flexibility of arrangement, since it is panel mounted and can be readily located in any part of the engine room.

It is often used where it is not convenient to provide space for the drum controller at the operator's post.

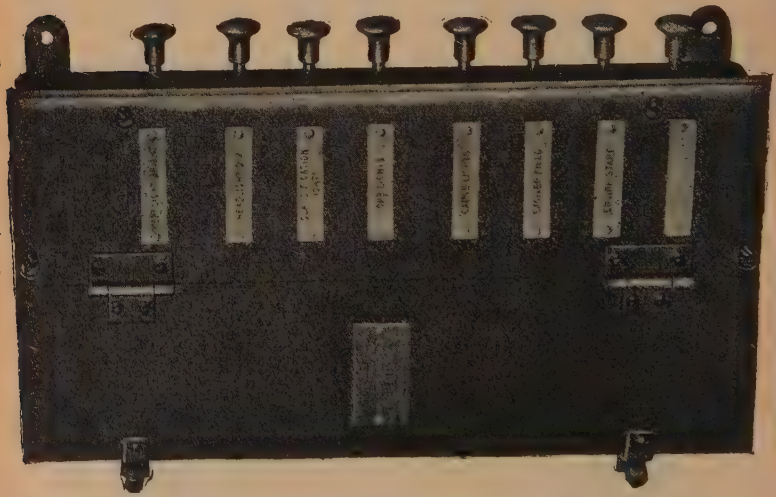


FIG. 6,140.—General Electric push button switch for control of lights, exciter field and engine start.

Air Compressors.—Motor driven air compressors are available in a large range of capacities. The sizes used for gas electric cars vary from 20 to 50 cubic feet of free air per minute. Compressors operate from the terminals of the dynamo through a pressure governor which automatically cuts off the power supply when the main reservoir is at the required pressure.

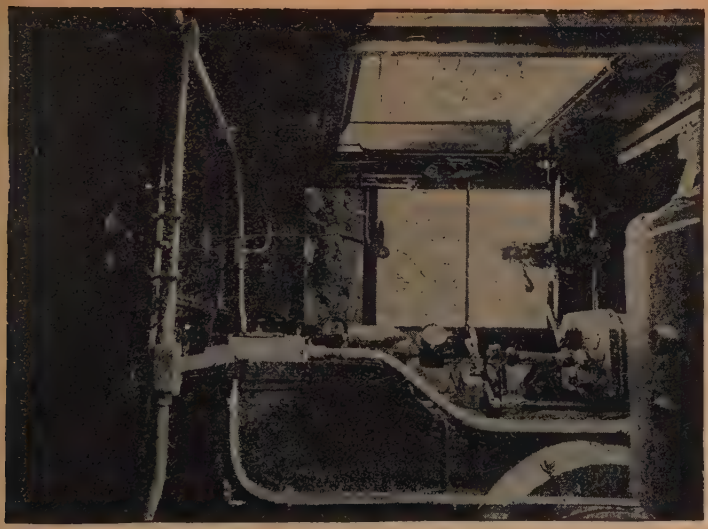


FIG. 6,142.—Interior operating compartment showing drum type control.

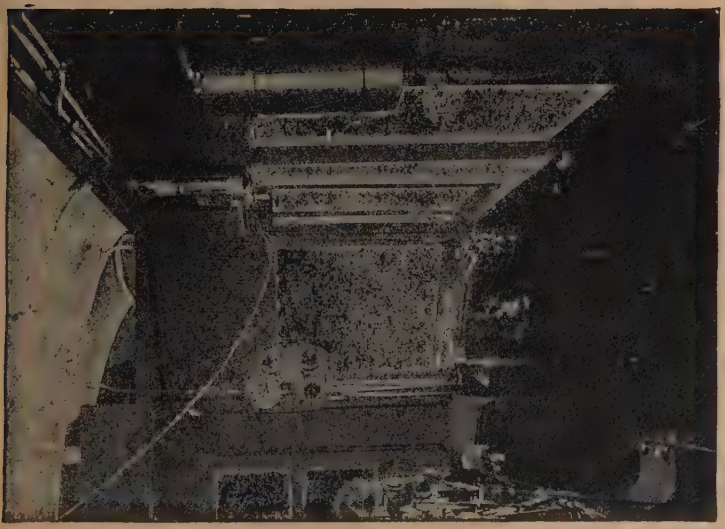


FIG. 6,141.—Interior operating compartment showing remote contactor control.

Battery Charging.—Each car is supplied with a storage battery for lights, control, starting and for energizing the field of the exciter. The battery is charged by the direct connected exciter through the B field of the dynamo, and a reverse current battery switch.

The B field absorbs any excess voltage difference between the exciter and the battery, and, at the same time, supplies necessary additional field excitation for the dynamo.

The charging rate to the battery is dependent upon the engine speed and the load on the dynamo, and can be adjusted and regulated by a by-pass

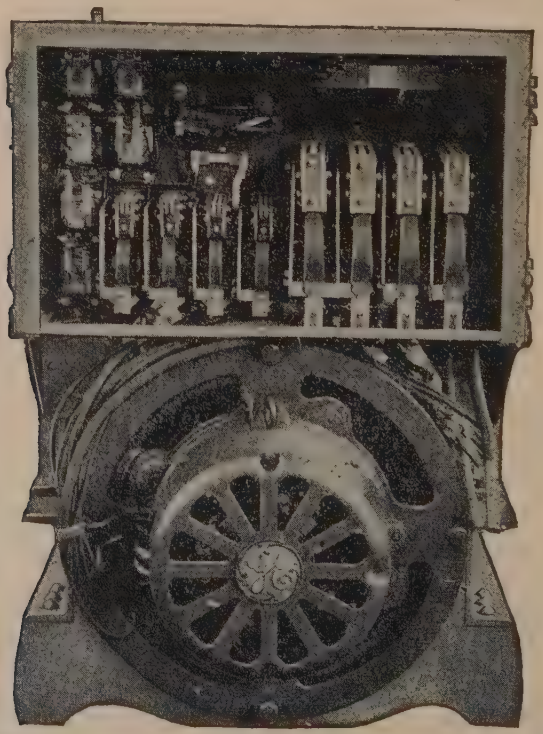


FIG. 6,143.—General Electric 135 *h.p.* unit with contactor control mounted above the dynamo.

resistance connected across the B field and having a switch to regulate it for three charging steps. This is so arranged that the car maintainers check the battery charging setting weekly, at the time of battery inspection. This scheme of battery charging is simple and reliable and gives long life to the storage battery. The small number of parts and the fact that it requires no adjustment are among the chief advantages.

Single Motor for Engine.—The usual gas electric car equipment has *two motors operating in series or parallel from one dynamo.*

Some car builders have found it desirable, because of engine size, to operate a single engine dynamo unit with a single

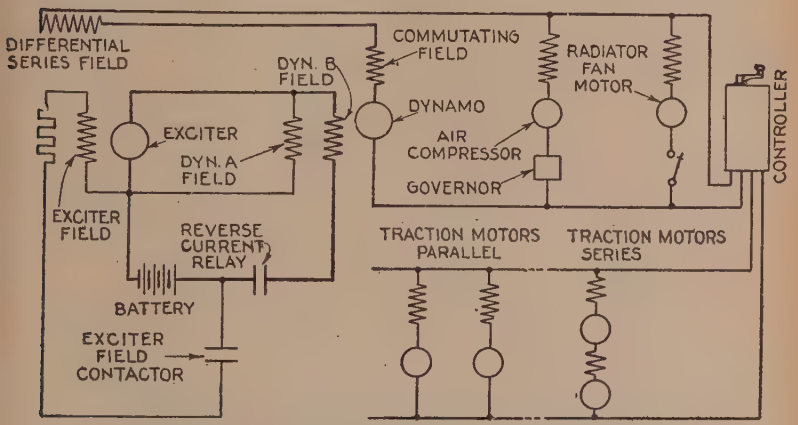


FIG. 6,144.—Diagram for gas electric car equipped with one engine dynamo set and two traction motors. The dynamo has a differential characteristic to give full engine output, and operates as a unit with the traction motors. The characteristic of the dynamo limits the power output so that at heavy loads, such as short circuits or heavy starting duty, it is impossible to stall or overload the engine. In addition, this characteristic is such that it does not unload the engine or cause it to race. This feature is obtained by a differential series winding mounted on the exciter and so designed that the power output is maintained within definite limits throughout the full operating range. As the current and voltage build up in the dynamo, the opposing effect of the differential winding limits the excitation of the dynamo in proportion to the amperes demanded. The two dynamo fields are energized by the direct connected exciter. The A field of the dynamo furnishes 70 to 85 per cent of the field excitation and the B field supplies the remaining field energy. As indicated previously, the B field absorbs any voltage excess between the exciter and the battery. The storage battery provides excitation for the exciter field and also is used to start the engine.

motor, two motors with two power plants, and even a triple power plant car with one motor connected to each dynamo.

In order to obtain equivalent operating conditions of the series parallel control with two motors and one dynamo, a dynamo with a dual voltage characteristic is used. The first or major characteristic is such that the dynamo is utilized at low voltage and high starting current for maximum tractive effort and acceleration, and the second characteristic supplies the high voltage for high and free running car speeds. This wide range dynamo characteristic is obtained by a slight modification of the standard scheme of connections.

The first characteristic is obtained in the usual manner by separate excitation of the exciter.

The second characteristic is obtained by self excitation of the exciter and the use of a voltage relay.

The combination of these characteristics with a single motor gives a constant engine output over a wide range of car operation comparable to the regular dynamo with two motors. The potential relay which operates at the voltage corresponding to the crossing of the two curves, automatically controls the changeover from the separate excited to the self excited dynamo operation. The important features of this scheme of control are simplicity and the absence of all torque or power relays.

Operation of Gas Electric Car.—The method of operating this type of car, which is similar to that of a steam locomotive, is by means of a throttle, air brake valve, and controller, the latter being similar to the reversing lever on the steam locomotive. The car is controlled entirely by the engine throttle. With the throttle in the "off" position, the operator first puts the controller in the series or first running position, and then opens the throttle. As the throttle is opened, the engine speeds up and the throttle switch, operating through a contactor, closes the battery circuit to the exciter field and supplies excitation to this unit. This, in turn, permits the voltage of the dynamo to build up and the car to start.

As the engine speed increases, the voltage of the exciter also increases, until it is above that of the storage battery, at which time the reverse current battery switch closes, and the exciter then charges the battery.

After the car has reached a speed of 10 to 12 miles per hour, the operator moves the controller from the series to the parallel position. This is done with full throttle and the transition of one motor connection to the next is made smoothly without hesitation or jolt to the car. As the car continues to accelerate, the controller is turned to the full speed or shunt field position. This last controller change is made at about 25 miles per hour.

To reduce the speed of the car, it is necessary only to ease off the engine throttle, which automatically gives a dynamo output proportional to the reduced engine power.

The B, field is valuable, as it increases the dynamo excitation at free running speeds of the car and supplements the differential characteristic to give increased power output from the engine. This also has the desirable feature of changing dynamo excitation rapidly with a slight change in engine speed, and assists in utilizing the full engine output over a comparatively wide range of current load and at the same time automatically reduces any excess load on the engine.

TEST QUESTIONS

1. *What is the most difficult problem facing the railroads?*
2. *To what cause is a heavy loss of railway business due?*
3. *What are the advantages of gas electric railway cars?*
4. *Give a general description of a gas electric railway car.*
5. *What range of* h.p. *is used for gas electric railway cars?*
6. *What are the characteristics of the engines used?*
7. *Describe a typical gas electric drive dynamo.*
9. *What kind of coupling is used between engine and dynamo?*

10. *How are the motors mounted?*
11. *Describe the control equipment.*
12. *Name two types of control used.*
13. *How are the air compressors driven?*
14. *How is current obtained for lighting?*
15. *Describe the various motor hook-ups.*
16. *Describe in detail the operation of a gas electric ca*

CHAPTER 132A

Diesel-Electric Locomotives

General.—Primarily a diesel-electric drive as used on locomotives is a self-contained system of power conversion in which diesel engine supplies power to the traction motors through an lectric generator which it operates.

There are three fundamental parts to the diesel locomotive ower system. They are:

1. The diesel engine;
2. The generator;
3. The traction motors.

The diesel engine drives the generator, and the generator roduces electrical power which drives the traction motors. ach traction motor is connected to an axle through pinion nd gear.

There are usually two traction motors for each power plant r four for each locomotive unit.

Ques. How does a diesel-electric locomotive function?

Ans. The function of a diesel-electric locomotive is quite mple; the engine drives the generator which produces elecicity to run the motors geared to the axles. When the throttle

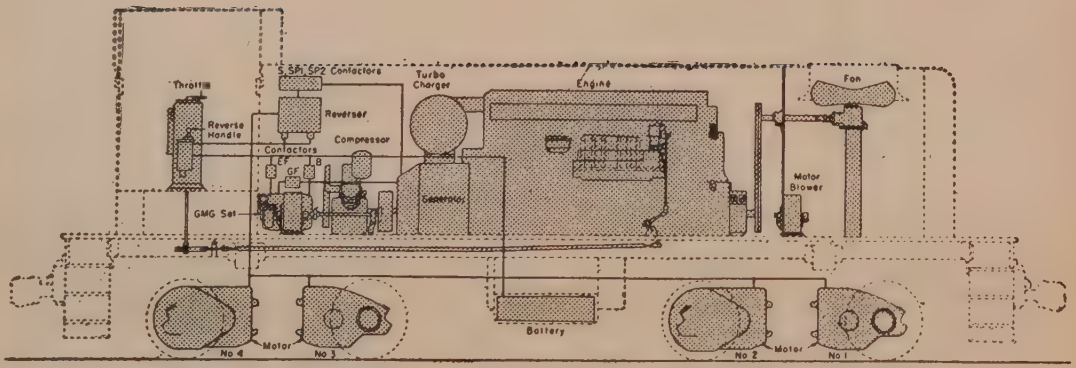


FIG. 6,144-1.—Schematic diagram showing arrangement of principal parts in typical diesel electric locomotive.

is opened, the generator is connected to the traction motors. Power then flows to the traction motors, and the locomotive moves. As the throttle is opened wider, the engine speeds up, delivering more power to the generator and thus the traction motors. When the throttle is wide open, the engine runs at a predetermined speed, usually from 740 to 1,000 *r.p.m.* The generator automatically adjusts its electric output to the motors so as to apply the required horsepower up to maximum rating for any combination of speed and load.

Ques. What is the construction of the main generator used on diesel electric locomotives?

Ans. The main generator is usually of the direct current, shunt wound commutating pole type. It is directly connected to the diesel engine through a flexible disc-type coupling and rotates in a counterclockwise direction looking at its commutator end. The generator frame is bolted to the engine structure and the generator feet are set on springs to take a portion of the overhung weight.

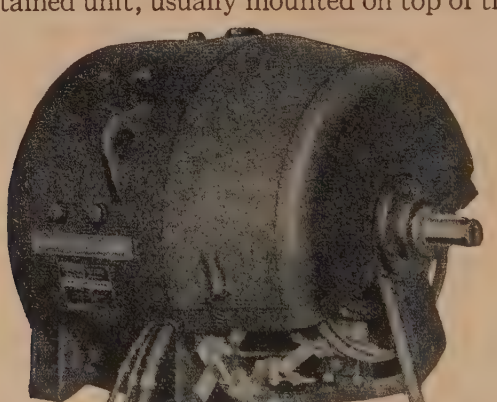
The generator is usually self-ventilated by a fan on the engine end of the armature. Main field excitation is supplied by a separate belt-driven exciter which governs the output characteristic of the generator. A starting field for cranking the engine is built in with the main field of the generator.

Ques. What is the purpose of the auxiliary generator?

Ans. The auxiliary generator supplies power for all low voltage circuits and for charging the locomotive storage battery. The armature is overhung on the main generator shaft extension by means of a tapered fit and the auxiliary generator frame is fastened to the main generator frame head. The field is self-excited and is externally controlled by an automatic voltage generator.

Ques. What is the purpose and construction of the exciter

Ans. To supply excitation to the main generator field. I is a self-contained unit, usually mounted on top of the auxiliary



FIGS. 6,144-2 and 6,144-3.—Showing commutator and coupling end, respectively, of typic traction generator. The generator is of the four-pole, direct current self-excited shu wound, commutating-pole type, and is designed for operation directly connected through flexible disc-type coupling to a diesel engine. It is provided with series winding for engi cranking purposes.

generator and is belt-driven from the main generator armature shaft. The exciter is of the two bearing type with a pulley on the shaft extension.

This machine is ventilated by a fan mounted on the armature. The exciter field poles are split in two sections and excited by shunt and differential windings. The differential winding is connected in series with the main traction circuit. The combined effect of the shunt and differential windings results in the combined generator exciter unit delivering its designed output.

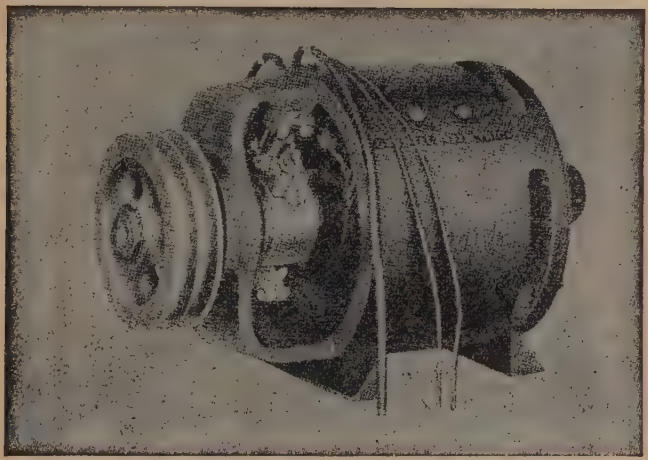


FIG. 6,144-4.—Typical auxiliary generator. The auxiliary generator is belt-driven from a sheave on the main generator shaft.

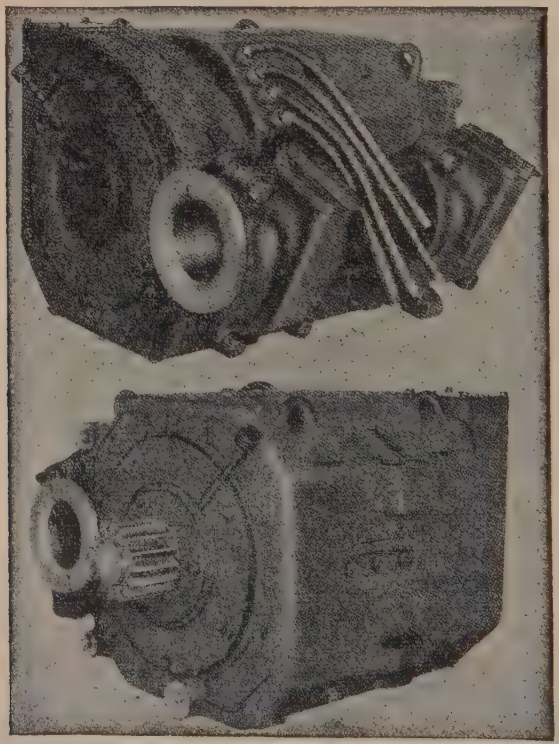
Ques. What is the construction of the traction motors?

Ans. Each direct current traction motor is of the box frame type carried on the trucks through two axle bearings and a spring nose support located on the truck bolster. Each motor has two grease lubricated roller bearings on its armature shaft. The axle bearings are waste packed and of the constant oil level type.

Each motor is pressure ventilated from belt-driven blowers located in the engine room. The gear case enclosing the motor pinion and axle gear is bolted to the motor frame.

Ques. How is the control of the traction motors obtained?

Ans. By transfer of motor connections. As the locomotive speed increases traction motor current will decrease and voltage will increase. To control the voltage and current relations



FIGS. 6,144-5 and 6,144-6.—Showing commutator and pinion end, respectively, of typical traction motor. The motor is of the four-pole, direct current, commutating type and is designed for use with an engine driven generator.

between the generator and traction motors, three different sets of motor connections are used. These connections are as follows: 1. *Series*—low to intermediate locomotive speeds. 2. *Parallel*—intermediate to medium high speeds. 3. *Field shunting*—motors in parallel with shunted or reduced traction motor field current—medium high to high locomotive speeds.

In *series* connection the current from the generator goes directly through one traction motor then through the second traction motor and back to the generator to complete the circuit.

In *parallel* the generator current is split, half of it going through one traction motor and half through the second motor, wires returning from each motor to the generator to complete the circuit.

In *field shunting* connection, a portion of the traction motor field current is by-passed through an electrical resistance with the main connections in parallel.

Each one of the foregoing steps will increase the generator current and reduce the generator voltage to keep the equipment within its operating range as the locomotive speed increases.

Ques. What are the main parts of the low voltage circuit?

Ans. The main parts of the low voltage circuit are the auxiliary generator, the batteries, and various control contactors and relays. The batteries are used to start the diesel engines and furnish standby power for control and lighting circuits. After the engines are started, the batteries have no function except to be charged by the auxiliary generators.

The auxiliary generators furnish low voltage electricity for all the locomotive auxiliaries, such as lights, fuel pump motors and the boiler. They furnish power to energize or close all the main power switches and relays. They also furnish a portion of the main generator exciter field current and power to charge the batteries.

Ques. What is the function of the field control or speed switch?

Ans. This switch is an automatic auxiliary regulating device applied to the generator field circuits so that the generator will

load the engine to maintain constant engine speed, in the event of any unusual loading condition. It functions only in the last operating notch. The speed switch varies the resistance in series with the field of its respective exciter at predetermined speeds of rotation. It is cut into the circuit only on the 8th throttle notch, by means of relay **CR2.**

The switch has but three leads leaving the housing. These are marked **C**, *1*, and *2*. The circuit between all three leads is normally open, but as the speed of rotation increases to that at which the switch is set to function, the circuits betwen *1*-**C** and *2*-**C** open and close at least once every revolution within an approximated range of speed of from 730 to 735 *r.p.m.* and will close fully at 735 *r.p.m.*

The main parts of the rotor are: a hub casting; a spring returned weight; three slip rings and two contact fingers. The hub is designed for mounting on the exciter shaft extension and it supports the three slip rings, also the hinged weight. The slip rings are insulated from the hub and also from each other by the tube and spool method.

Control Equipment

This is the heart of any diesel-electric locomotive. Conveniently grouped at the operator's station are the throttle handle, reverser handle, brake valves, sander valve, bell and horn controls, window wiper valves and switches for lights, engine starting and control. The purpose of the various controllers, push buttons, magnet valves, etc., of a typical diesel-electric locomotive as manufactured by the *American Locomotive* and the *General Electric Company's* are given on the following pages.

"A" and "B" Units.—A diesel-electric locomotive of this type is divided into two power plants or units termed **A** and **B.** The back end of the **A** unit is fitted with a standard passenger vestibule diaphragm. The **B** unit is similar to the **A**, except the operation cab is omitted at the forward end where additional water tanks are located.

"A" Lead Unit.—The electrical equipment for the No. 2 diesel engine is in general similar to the equipment for the No. 1 diesel engine. The identification symbols for the No. 1 engine transmission are noted by letters and single digit numerical symbols, whereas the transmission units for the

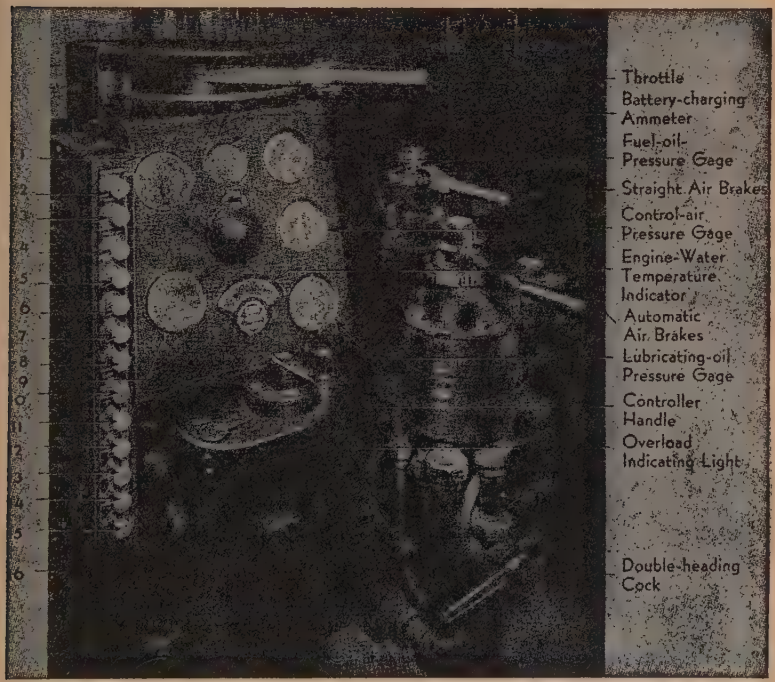


FIG. 6,144-7.—Showing various controls at engineman's position. The figures indicate as follows: **1**, main and equalizing reservoirs air gauge; red is main reservoir pressure and white is equalizing reservoir pressure; **2**, engine-start switch; cranks engine from the battery; **3**, control switch; energizes control circuits; **4**, fuel pump switch; starts fuel oil pump motor; **5**, **6**, **7** and **8**, headlight switches; for bright first close *dim* switch and then *bright* switch; **9**, brake cylinder and brake pipe air gauge; red is cylinder pressure and white is pipe pressure; **10** and **11**, switches for *gauge* and *dome* lights; **12**, switch for engineroom lights; **13** and **14**, number lights and marker light switches; **15**, heater switch; starts cab-heater motor; **16**, wheel slip buzzer; warns of wheel slipping.

second engine are denoted by the same letters and double digit symbols. For instance, the generator in the No. 1 power plant is symbolized by **G1** and the No. 2 power plant generator is **G2**; No. 1 power plant contactors **P1**, **P2** and No. 2 power plant contactors **P21** and **P22** and so forth.

"B" Booster Unit.—The electrical equipment on the **B** unit is practically a duplicate of the electrical equipment on the **A** unit. Therefore, for information about the **B** unit electrical equipment, refer to similar headings for the **A** unit.

Ques. What is the purpose of the master controller?

Ans. The purpose of this controller is to control the speed of the locomotive and to fix its direction of motion. The controller has two handles: the *throttle* and the *reverse* handle. It also has a number of cam operated hinged type contacts which are connected in the control circuits. At the top of the controller is a notched ring segment against which presses a pawl. The arrangement is such that the throttle must be notched slowly from one position to another.

The throttle and the reverse handle are so interlocked that the reverse handle is removable in the *neutral* position only when the throttle is in the off or *idling* position. When the reverse handle is removed, the throttle cannot be moved from the *idling* position. The mechanical interlocking also prevents moving the reverse handle into or out of the off position unless the throttle is in the *idling* position.

With the reverse handle in place, it is possible to move the throttle to any position. Thus, with the reverse handle in the off or *neutral* position, the throttle may be moved to any position for engine testing purposes.

Ques. What is the purpose of the master controller on the B unit?

Ans. The purpose of this controller is to fix the direction of motion and speed of the booster unit when it is being operated alone.

The controller has a throttle lever and a reverse handle. It also has a number of operated hinged type fingers which are connected in the control circuits. The mechanical interlocking of the throttle and reverse levers is the same as for the **A** unit, except that when the reverse lever is either removed or in the off position, the throttle cannot be moved from the *idling* position.

Ques. How is multiple unit operation accomplished?

Ans. In multiple unit operation the **B** unit is connected to **A** unit and the **A** unit controls operation of both units. The throttle on the **B** unit master controller is moved to the *idling* position, and its reverse lever removed from the controller. This is to prevent unauthorized movement of the operating lever when the units are controlled from the head end of the **A** unit. During multiple unit operation, the action of the reverse, contactors and motors is controlled entirely from the master controller in the **A** unit.

Ques. Where are the push button control switches located and what circuits do they control?

Ans. Push button control switches are located at the engineer's operating position for controlling various lighting and control circuits. One switch is used for controlling lighting circuits and the others are used for the various main control circuits and for attendant calls.

The switch for the main control circuits is also provided with a lock at the top of the switch. Before operating any of the buttons, insert the key and turn it to the running position. Since the key is removable in the locked position, no operation of the locomotive can be obtained unless the key is in place. Only one key is provided, thereby making it impossible for anyone except the proper authorized person to operate the locomotive.

Another push button control box is located at each engine control station. Each box has a fuel pump switch, engine starting switch and engine control or isolation switch. There are four individually fused circuits in the box, two of the circuits being operated by the engine start button. These switches handle all of the 75-volt control circuits. Care should, therefore, be taken when removing fuses to see that the particular button controlling the circuit in which the fuse is located is in the open position.

Ques. What is the purpose of the isolation switches and engine control buttons?

Ans. The third button on the control box at each engine control station is marked *Engine No. 1* or *Engine No. 2*. Its purpose is to enable the operator to isolate one of the power plants in case of trouble. When the button is pulled out the EV magnet coil is de-energized and the main generator field circuit is held open through an interlock on the oil pressure relay. Thus the engine will not run at any speed except idling and no power can be transmitted from the generator to the traction motors.

Ques. What are the magnet valves used for?

Ans. The magnet valves are used to actuate the motor reverser, the governor operating mechanism, the engine control, and the air operated contactors, and are all of the so-called *ON* type. Some have enclosed coils and some have open coils. The *ON* type magnet valve is of the double acting type and has an inlet and an exhaust port as well as a port for connecting to the operating cylinder. This valve is so constructed that when the coil is energized the exhaust port is closed and the inlet port opened, thus admitting air from the reservoir to the operating cylinder. When the coil is de-energized the inlet port is closed and the exhaust port is opened and thus connects the cylinder to atmosphere.

Ques. What is the purpose of the electrical interlocks?

Ans Electrical interlocks are provided for most of the electro-pneumatic and magnetic contactors, relays and the reversers. The interlocks are connected in the circuits of the operating coils of the various devices so as to prevent them from operating until some other essential operation has first taken place.

The interlocks used on the magnetic contactors consists essentially of a contact bar or bars attached through insulation to the contactor armature and contact fingers which are attached to the contactor frame through insulation. The electro-pneumatic contactors are equipped with sliding contact type interlocks consisting of insulated segments and fingers which are attached to the contactors.

Ques. How does the throttle operating mechanism function?

Ans. An electro-pneumatic mechanism is mounted on each engine to operate its Woodward governor. The mechanisms operate electrically in steps under the control of the throttle on the master controller.

Each mechanism consists of three small air cylinders and pistons actuating a lever attached to the Woodward governor. The governor is held in its idling position against the pressure of its speeder spring. The three pistons move the main lever by means of rollers and a system of interconnecting levers and links so that the lever assumes seven definite progressive positions after leaving the idle position as the air cylinders are energized in different combinations. The cylinders are supplied with air by individual magnet valves. There is also a master valve, called the EV magnet valve in the airline to the throttle mechanism. Each successive step of the lever compresses the governor speeder spring and raises its engine regulating speed. The full travel of the end of the lever from idle to full speed is $1\frac{1}{32}$ in.

Ques. What is the purpose of the reversers for the traction motors?

Ans. The purpose of the reversers is to change the connections to the traction motor fields and thus reverse the direction in which the locomotive will move.

This reverser is of the electro-pneumatic type and is operated by a double cylinder air engine controlled by two *O N* type magnet valves. The reverser is electrically interlocked so that it cannot be operated except with the motor contactors open. Leads from the traction motors are connected to the reverser terminals and the operation of the reverser changes the direction of the flow of current through the fields, thereby reversing the rotation of the motors.

Series Contactors S1, S21.—These are of the electro-pneumatic type with electrical interlocks. They are used in the motor circuit to connect the motors on each truck in series. They are electrically interlocked with the parallel contactors, so that the parallel contactors cannot operate while the series contactors are closed and vice versa.

Parallel Contactors P1, P2, P21, P22.—These are of the electro-pneumatic type, using air pistons to close the contactors against heavy springs. They are electrically interlocked with the series contactors and the generator field contactors and others, so that the series contactors cannot close while the parallel contactors are closed and the generator field contactor cannot close until the proper motor contactors are closed.

Field Shunting Contactors and Interlocks M1, M2, M3, M4. The field shunting contactors and interlocks are of the silver faced contact type. They are used for connecting the motor field shunting resistors in the circuit. They are under the direct control of the voltage control and field shunting transfer relays.

Time Delay Control Relay TDR1, TDR21.—This relay is used in the traction motor field shunting circuits. It inserts a one second time-delay in operation when going back from field shunting to full field motor connections. Its purpose is to give any possible surges time to die out before the field shunting

relay can pick up again. A copper cylinder around the core inside its coils causes a one second delay in the drop out action.

This delay inserts resistance in series with the shunt coil of the field shunting relay so that the latter cannot pick up for one second. This delay in transition in going back from *field shunting* to *full field* connections permits any possible surges to die out before the field shunting relay picks up and establishes the full field motor connections.

Traction Motor Transfer and Field Shunting Control Relay V1, V21.—This relay automatically transfers the motors from series to series-parallel and operates the field shunting contactors at the proper times. The relay operates with each successive rise of generator voltage, advancing the motor connections from series, to parallel, to field shunting.

An insulated base supports an inverted T-shaped magnetic frame to which a double acting balanced armature is pivoted.

With both coils de-energized the contacts are held in the open position by the armature spring, which forces the lower plunger against its core. The upper (shunt) coil is connected in series with suitable external resistors, across the main generator armature and thus the current through it is proportional to generator voltage. The lower (series) coil is connected in parallel with the main generator and exciter series field windings and its current is proportional to generator current.

The relay will operate at relatively low voltage with no load on the generator. The pick up voltage increases rapidly with increasing generator current. In this manner transition will occur at very nearly the same locomotive speed regardless of the notch on which the throttle is set.

Wheel Slipping Relay WS1, WS21.—This relay is provided to measure the difference in voltage between the respective motors of each pair of traction motors when operating in the series connection. In the event either wheel slips, its motor voltage increases, while the voltage on the other motor decreases. This difference in voltage causes the relay to be

energized and operate the warning light. It also prevents transfer to parallel motor connections taking place while the slipping lasts.

After parallel connections are established, interlocks on **P2** and **P22** disconnect the relays. The relay works momentarily whenever a power plant transfers from series to parallel so that a brief flash of the indicating lamp will not mean wheel slipping, but will indicate that transfer has taken place on one power plant. A subsequent brief flash shows that another plant has undergone transfer from series to parallel connections.

Engine Starting Contactors with Interlocks GS1, GS2, GS21, GS22.—These contactors are of the magnetic type and are used for connecting the starting winding of the generator to the storage battery for starting the engine. They are electrically interlocked with the other control apparatus so that when they are closed, the generator field contactor and other contactors are locked open so that no power current can be applied to the motors until the starting contactors open.

Reverse Current Relay RC1, RC21.—The purpose of this relay is to prevent the battery from discharging through the auxiliary generator if the voltage regulator cannot hold the auxiliary generator voltage up to its predetermined setting by reason of the engine speed being too low or other cause. It governs the action of the battery charging contactor **B1, B21**, closing it whenever the auxiliary generator is developing sufficient voltage to charge the battery and opening the contactor whenever the auxiliary generator voltage falls appreciably below the battery voltage, 2 or 3 volts.

The relay has two operating coils, one of which, the shunt coil, is connected in series with a resistor tube across the auxiliary generator; the other, a series coil, is connected so as to carry the total current supplied to the battery circuit. This includes all battery loads as well as the actual battery charging current.

The series coil is connected so as to aid the shunt coil when current is flowing from the generator to the battery and to oppose it when the current reverses. Since the series coil is not connected in the circuit until the battery charging contactor is closed, it has no affect on the pick-up voltage, but will govern the drop-out voltage.

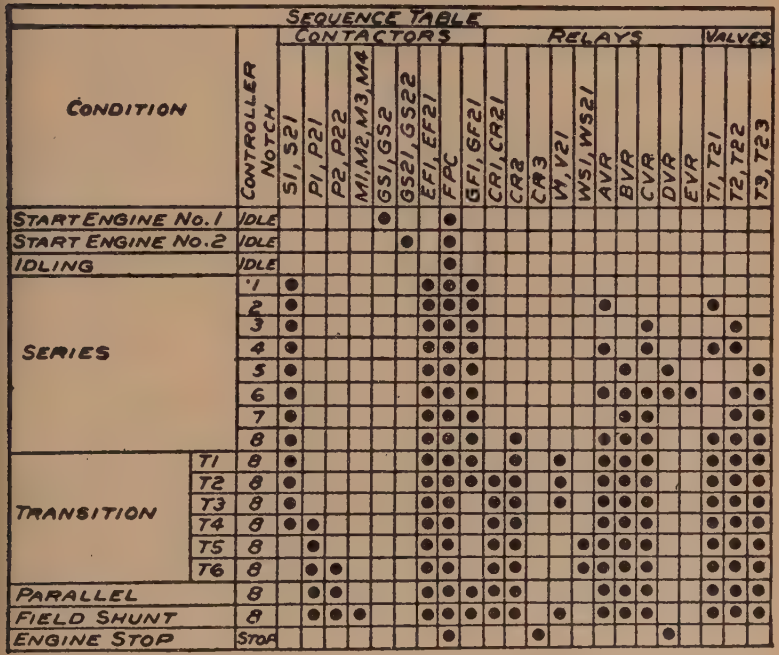


FIG. 6,144-8.—Contactor and relay sequence table. The sequence of the various contactors, relays and magnet valves for each throttle notch and transition point is spotted in the accompanying table. This sequence is based on transfer from motors in series to motors in parallel occurring on Notch 8 and simultaneously in both plants. This transfer may occur on one plant a little before the other, and it may occur on any notch. If it occurs prior to Notch 8, sequence of motor contactors is the same, but the sequence of **AVR, BVR, CVR, DVR, EVR** relays and **T** valves is completed afterwards. Not shown are the **B1** and **B21** contactors which are controlled by **RC1** and **RC21** relays. They are normally closed at all times after engines are running. The circuit relations between the various components of the locomotive electrical equipment are shown in a series of eight schematic diagrams, figs. 6,144-9 to 6,144-16.

Battery Charging Contactor with Interlock B1, B21.—The battery charging contactor is of the magnetic type and is used to connect the storage battery to the auxiliary generator for charging purposes. This contactor is directly controlled by the reverse current relay, so that it will not operate until sufficient voltage is flowing to charge the battery against the battery voltage. It is also suitably interlocked with other control equipment so that other contactors will not operate until the battery charging contactor is closed.

Voltage Control Relay X1, X21.—The relay is a dynamic type, voltage regulating device, equipped with a counterweight for smooth operation under rough track conditions. Constant voltage is held on the auxiliary generators over the normal speed and load ranges. Special connections are provided so that the auxiliary generators operate in parallel when both engines are running.

Whenever the auxiliary generator voltage exceeds the calibration value, resistance is cut into the shunt field circuit to restore the voltage to normal. The opposite action takes place upon a decrease in voltage.

Any circulation of current between the two auxiliary generators when operating in parallel, creates voltages of opposite polarity across two halves of a resistor. This changes the regulator coil currents, tending to lower the voltage setting on the auxiliary generator transmitting the circulating current and to raise the setting on the auxiliary generator receiving the circulating current.

Electrical Indicating Instrument V, BA, 142A, 132B.—The locomotive is equipped with a voltmeter in the battery charging circuit and with ammeters in the battery and traction motor circuits.

The instruments operate on the D'Arsonval principle, using a permanent magnet for the field and a coil on the moving element for the armature. On account of the high current on

which ammeters operate, they are provided with external shunts to carry the heavy current.

The ammeters in the main power circuits are calibrated into operating zones and are called *load indicators*. The engineman must be careful to follow the operating instructions regarding the load indicating zones so as not to damage the motors and generators in the main circuits.

The battery meters should be observed periodically to insure proper charge and prevent a run down battery on the road.

The charging current should be between 0 and plus 5 amperes. Immediately after starting up a diesel engine the charge current will be high (about plus 50) but this will return to normal in a few minutes as soon as the battery voltage is brought back up to normal.

The battery voltmeter should read 75 volts (approximately) when the diesel engines are running and 64 volts when they are shut down.

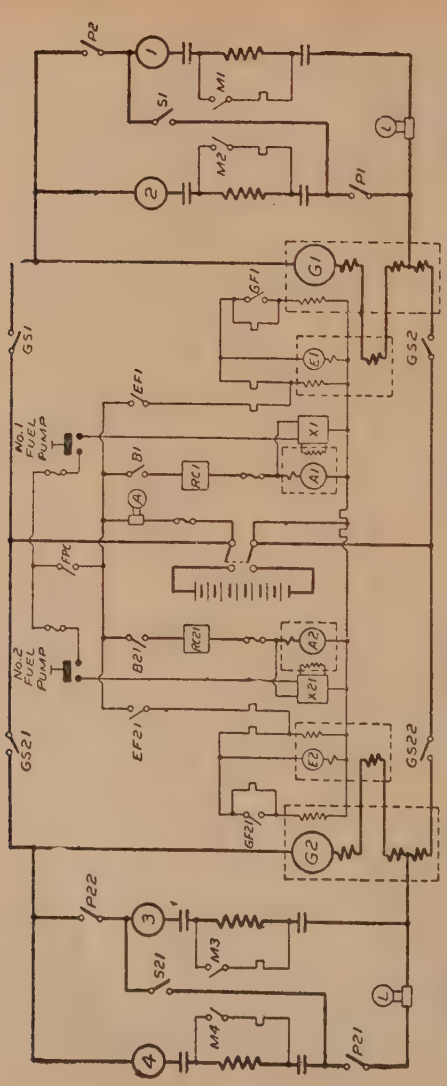
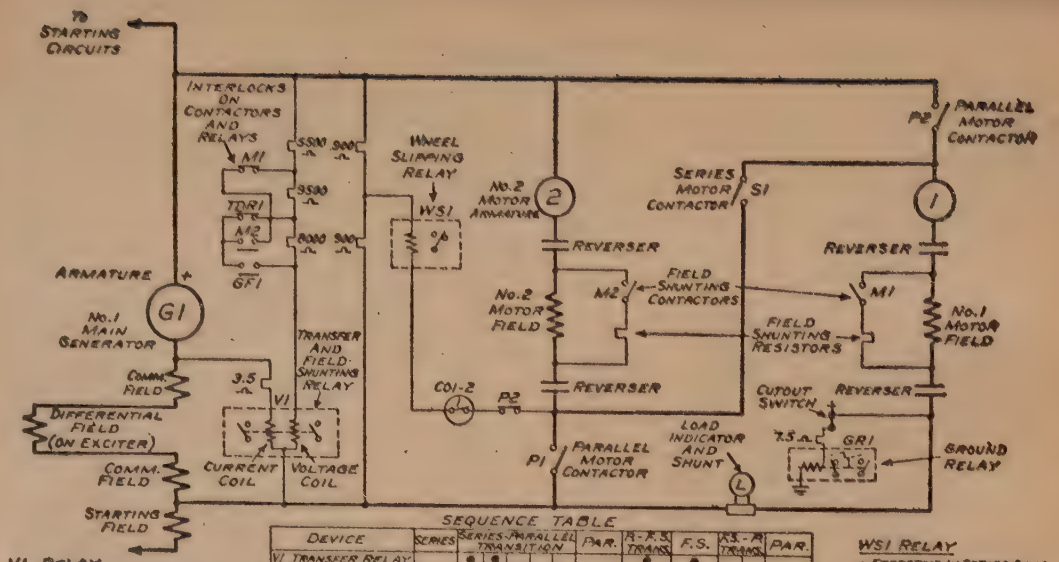


FIG. 6.144-9.—The elementary power circuits with principal connections between motors, generators, exciters, auxiliary generators and battery



SEQUENCE TABLE

Device	Series	Series-Parallel Transition	Par.	S-P.S. Trans.	F.S.	FS-P Trans.	Par.
V1 Transfer Relay		• •		•	•		
TDR Time Delay Relay					•	• •	
GF1 Gen Field Cont.	•	•	•		•	• •	
S1 Series Cont.	•	• •			•		
P1 Parallel Cont.		•	•	•			•
P2 Parallel Cont.			•	•	•	• •	•
M1 F. Shunt Cont.					•	•	
M2 F. Shunt Cont.					•	•	

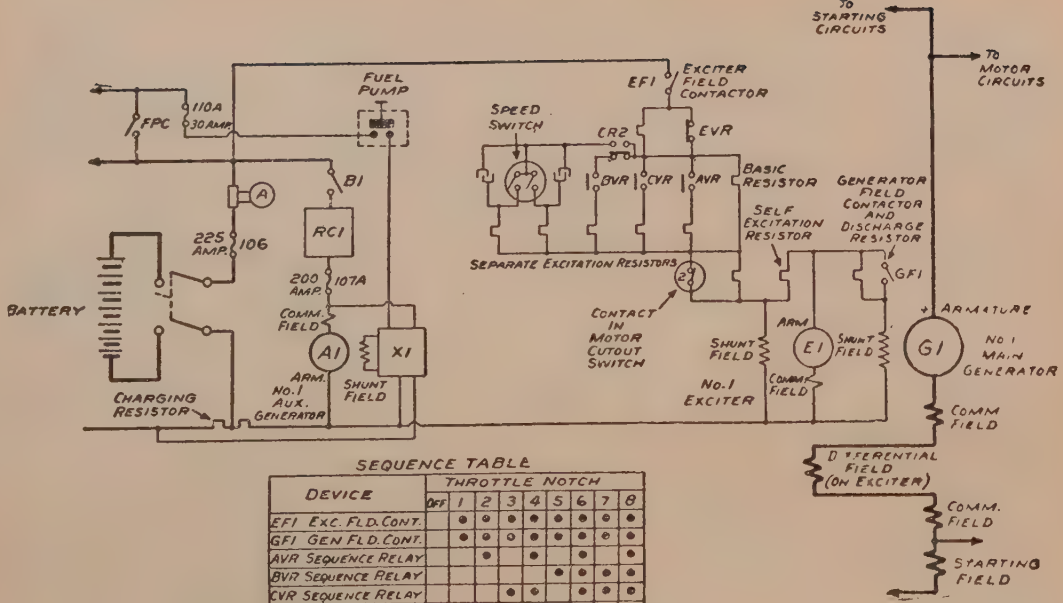
V1 Relay

- Initiates transitions forward from series to parallel, and into and out of field shunting (in parallel) at proper generator volts and amperes.

WS1 Relay

- Effective in series only.
- Operates momentarily during S-P transitions.
- Cutout entirely by Co1-2 motor cutout switch contact (1) when either motor 1 or 2 is cutout.

FIG. 6,144-10.—A typical traction power circuit with connections for the associated operating and protective relays.



SEQUENCE TABLE

DEVICE	THROTTLE NOTCH							
	OFF	1	2	3	4	5	6	7	8
EF1 EXC. FLD. CONT.		●	●	●	●	●	●	●	●
GF1 GEN FLD. CONT.		●	●	○	●	●	●	●	●
AVR SEQUENCE RELAY			●		●		●		●
BVR SEQUENCE RELAY						●	●	●	●
CVR SEQUENCE RELAY				●	●		●	●	●
EVR SEQUENCE RELAY							●		
CR2 CONTROL RELAY									●
SPEED SWITCH	REGULATES OPEN ON OVERSPEED, CLOSED ON UNDERSPEED								●

FIG. 6,144-11.—Typical traction excitation circuits.

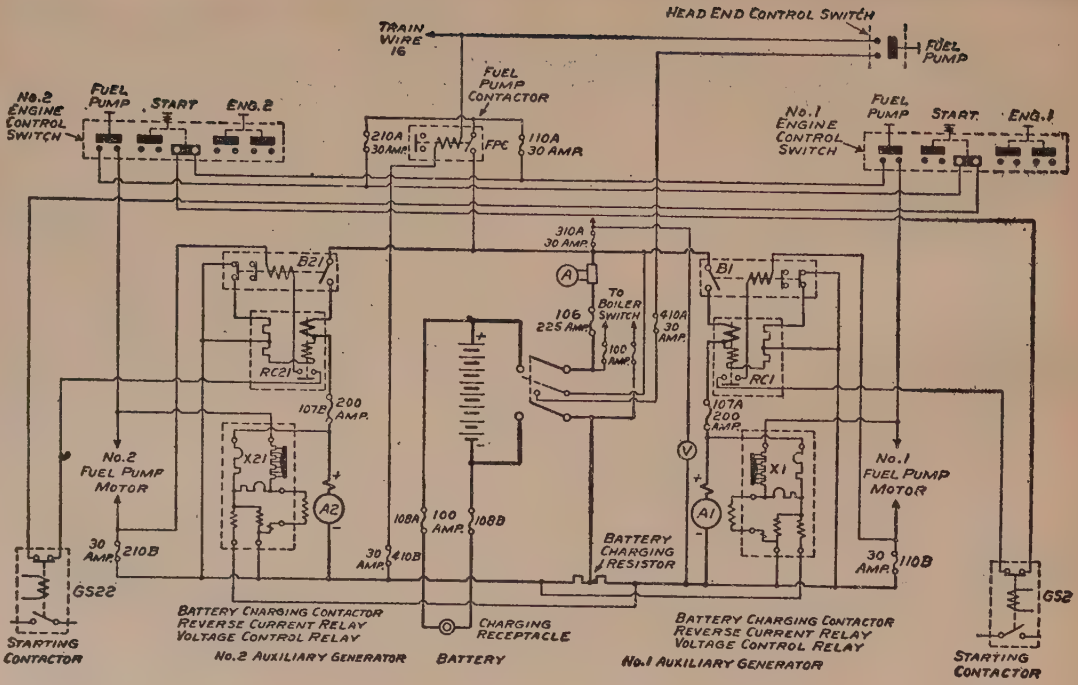


FIG. 6,144-12.—Typical battery charging circuits.

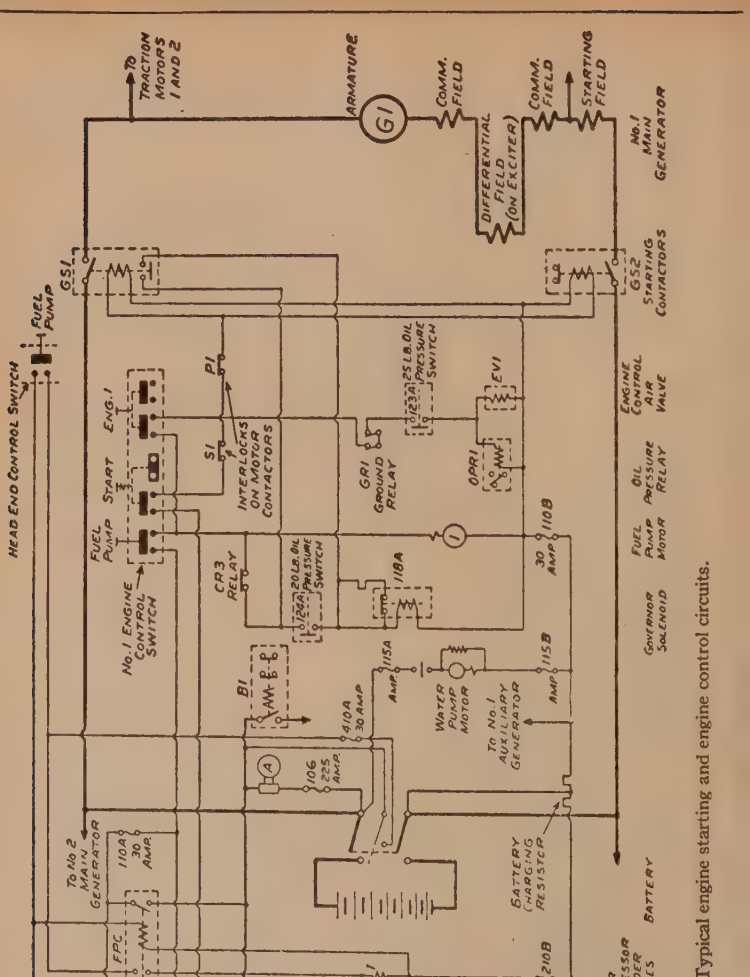


FIG. 6,144-13.—Typical engine starting and engine control circuits.

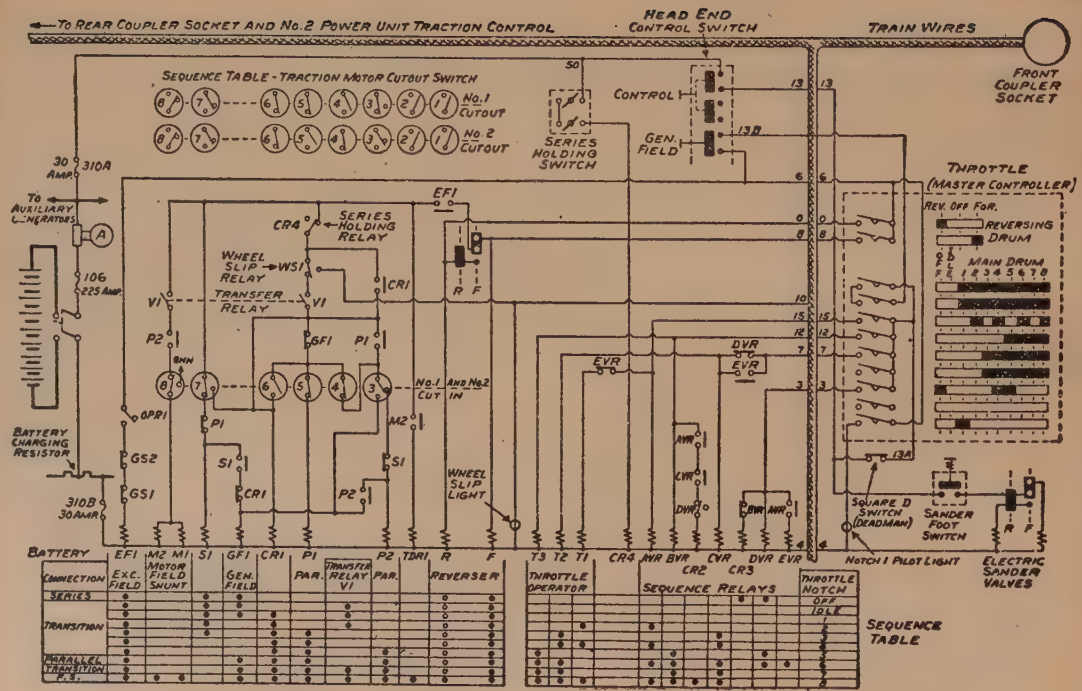


FIG. 6,144-14.—Typical traction control circuits.

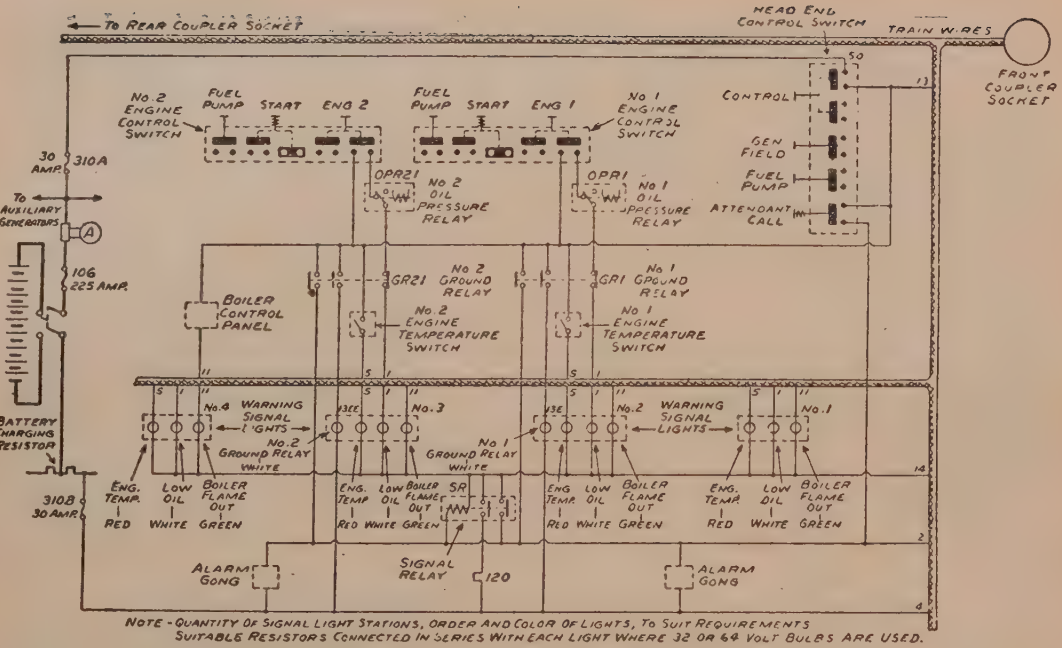


Fig. 6,144-15.—Typical alarm and signal circuits.

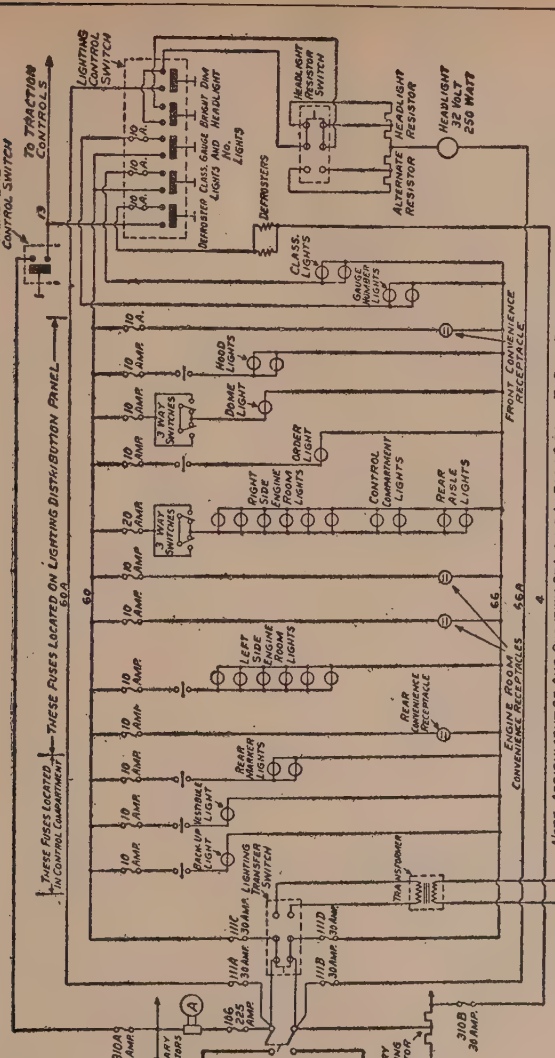


Fig. 6,144-16.—Typical lighting circuits.

TEST QUESTIONS

1. *What are the fundamental parts of a diesel-electric locomotive?*
2. *Describe briefly the function of a diesel-electric locomotive.*
3. *How many traction motors are there for each locomotive unit?*
4. *How are the main generators connected to the diesel engine?*
5. *What are auxiliary generators used for?*
6. *What are the three different sets of motor connections used to control the speed of traction motors?*
7. *Give the purpose and function of the master controller.*
8. *How many power plants does a diesel-electric locomotive usually have?*
9. *What is meant by the term multiple unit operation?*
10. *How may the rotation of traction motors be reversed?*
11. *What is the function of the field shunting contactors and interlocks?*
12. *In case of wheel slipping, what takes place to notify the operator?*
13. *What electrical instruments are used on diesel-electric locomotives?*

CHAPTER 133

Electric Locomotives

The designing and building of a successful electric locomotive, calls for a combination of the highest type of electrical and mechanical engineering skill. Such a locomotive must be considered not only as a transformer of power, but also as a vehicle; and the experience acquired in steam locomotive building and operation is invaluable in railway electrification work.

Electric locomotives may be classified

1. With respect to the drive, as
   - *a*. Gearless;
   - *b*. Geared.
2. With respect to the current, as
   - *a*. Direct { from dynamos; / from storage batteries.
   - *b*. Alternating;
   - *c*. Gas electric;
   - *d*. Oil electric;
   - *e*. Diesel electric.
3. With respect to voltage, as
   - *a*. Low;
   - *b*. Medium;
   - *c*. High.

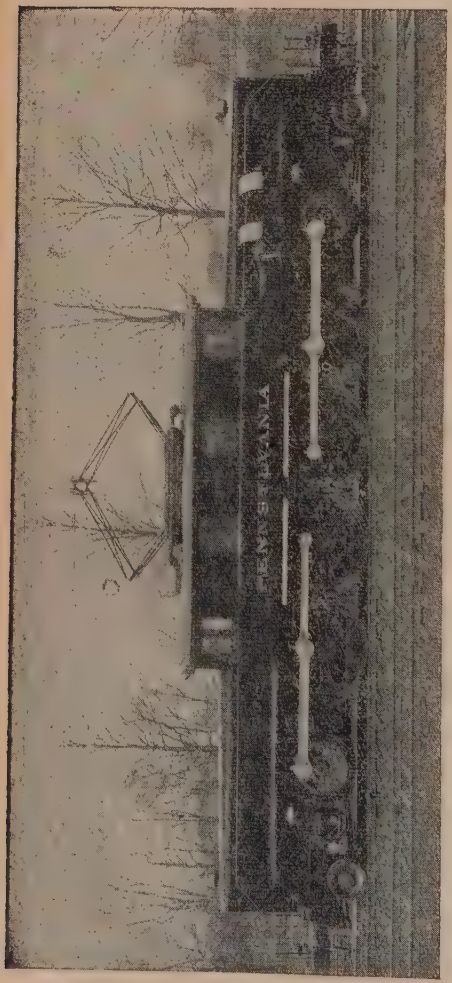


FIG. 6,145.—Westinghouse 204.3 ton, 11,000 volt, single phase motive power unit for freight service.

4. With respect to the collecting device, as

a. Trolley;

b. Pantagraph;

c. Third rail.

5. With respect to the application of the current, as

a. Direct connected;

b. Transformer;

c. Motor generator.

6. With respect to service, as

a. Passenger { short haul; interurban; local; express; heavy; trunk line.

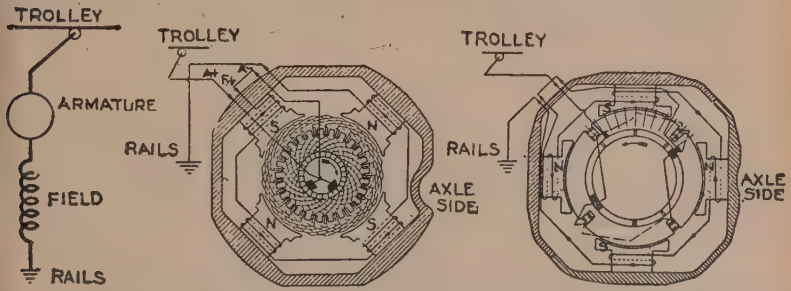
b. Freight { industrial mine.

c. Switching.

Motors.—Except in a few instances, city and interurban electric

railways employ *d.c.* motors of the series type, supported by the truck transom and axle, geared to the axle and entirely or partially enclosed for protection against water and dirt.

FIG. 6,146.—General Electric 60 ton storage battery type industrial haulage locomotive. The particular application is handling heavy loads for short hauls as is found in yard shifting, dock service, quarries, etc. Operation and repairs can be performed by men of ordinary ability.



FIGS. 6,147 to 6,149.—Electric circuits of the simple series motor. As shown in these illustrations the motors have four poles and the armature winding is of the two circuit wave length which permits the use of only two sets of brushes, makes cross connections unnecessary, requires the fewest number of turns per coil, the largest and therefore strongest conductors, and the least voltage per coil. The majority of railway motors still in service are of this type.

The series type motor is so called because *the same curren passes through the field and armature windings consecutively o in series*. The electrical circuits of the simple series motor are illustrated in figs. 6,147 to 6,149.

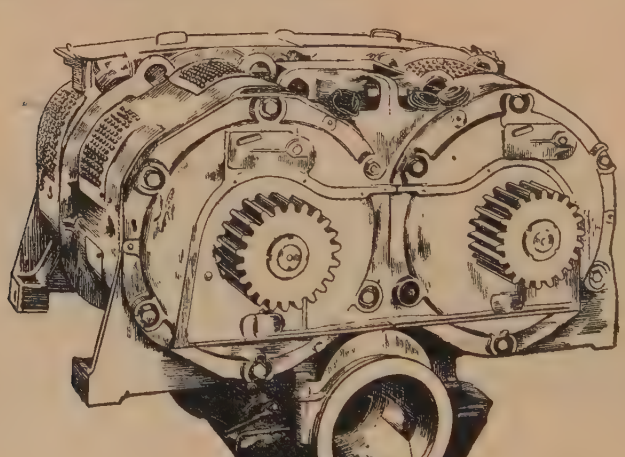


FIG. 6,150.—Westinghouse twin motor used on freight locomotives and high speed passenger locomotives. Note that two motors drive one pair of wheels. The same type motor in a suitable frame is used in multiple unit cars.

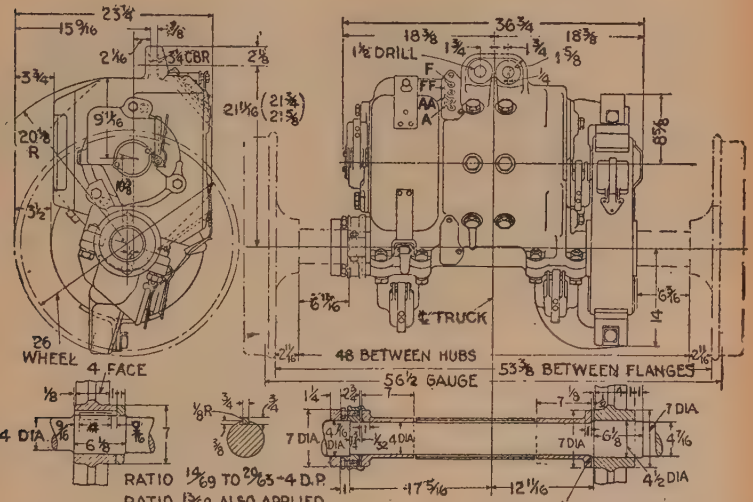
An improvement in railway motors was the introduction o the commutating pole.

This feature improves the commutation, reduces the wear of brushes and commutators, and makes possible the use o field control and high voltage systems.

The commutating pole series motor is now the standard for *d.c.* railways, and is shown in figs. 6,156 to 6,158.

Field Control.—A further development is the field control motor as shown in figs. 6,159 and 6,160. The idea of securing

additional efficient running speeds by varying the effective field turns on a railway motor is an old one, but on account of commutation difficulties it did not prove successful until the commutating pole was developed.

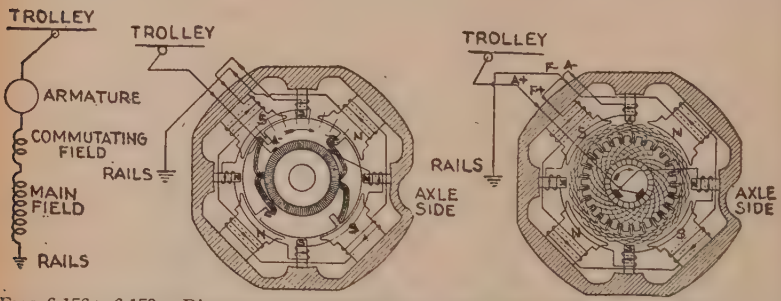


FIGS. 6,151 to 6,155.—Westinghouse box frame commutating pole direct current railway motor details.

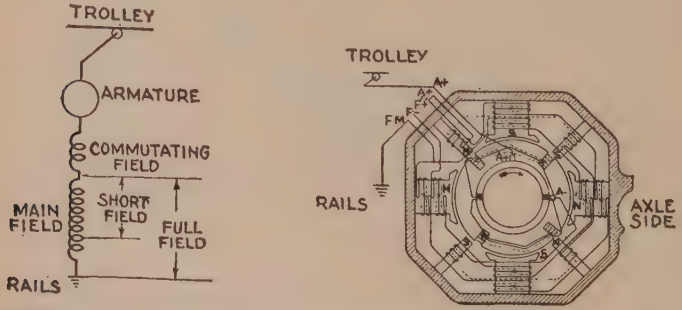
The field control motor has *the field arranged in two parts which are connected in series with a lead brought out from the point FM, where they are joined together, as in* fig. 6,160.

In starting, the entire motor current passes through both parts of the field in series, called the full field connection, setting up a very strong field and developing a large torque with a relatively small current. When desired, one portion of the field is cut out, leaving only the short field in the circuit, so that a comparatively weak field results and higher speeds are secured. These arrangements give economy and flexibility, in that less

starting current is required and the motor provides two efficient running connections instead of one. Fig. 6,160 shows the ground connection for the short field position.



FIGS. 6,156 to 6,158.—Diagrams of commutating pole series motor. The commutating pole improves the commutation, reduces the wear of brushes and commutators, and makes possible the use of field control and high voltage systems.



FIGS. 6,159 and 6,160.—Diagrams of field control motor.

NOTE.—***In practically every instance,*** where railways have been electrified the change has been made because under the special conditions existing, electric locomotives could accomplish results that were impossible with steam operation. A study of the leading characteristics of steam and electric locomotives will explain the reason for this. The steam locomotive generates its own power and its output is limited by the capacity of the boiler. The electric locomotive, on the contrary, is simply a transformer of power, and with ample power house capacity behind it there is practically no limit to its output. The maximum tractive force of both types is, of course, primarily dependent upon the weight on the driving wheels, but after the train is started the maximum speed of the steam locomotive, especially on ascending grades, is limited by the steaming capacity of the boiler; while the electric locomotive is limited by the capacity of its motors.

Ques. How is the voltage reduced in electric locomotives from high tension to low tension for the motors?

Ans. By step down transformers contained in the body of the locomotive.

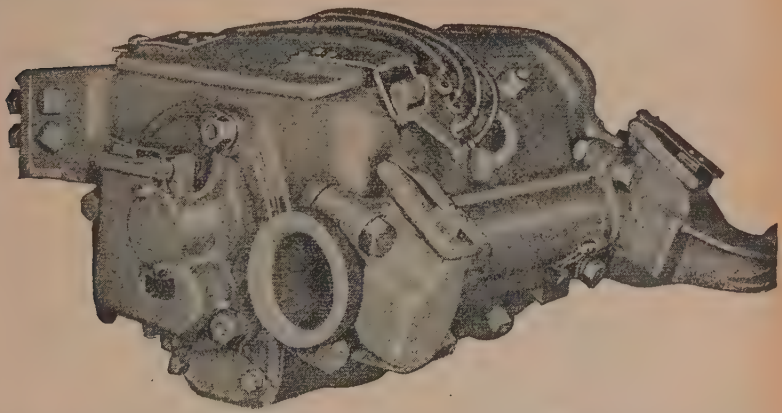


FIG. 6,161.—Westinghouse railway motor, 60 *h.p.*; 600 volts; 87 amperes, 770 *r.p.m.* suitable for light weight interurban cars where high running speeds are necessary, in double equipments on modern city cars and in quadruple requirements for trailer hauling. It is adaptable to all conditions requiring a 60 *h.p.* motor with 26 in. or 28 in. wheels.

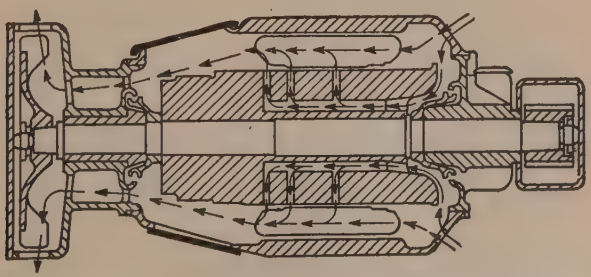


FIG. 6,162.—Westinghouse non-ventilated motor arranged for ventilation with an external fan. The fan is attached on the end opposite the pinion and its method of drawing the air through air ducts provided for the purpose is indicated by the arrows. Cooling a motor increases its capacity and it can be used for heavier loads.

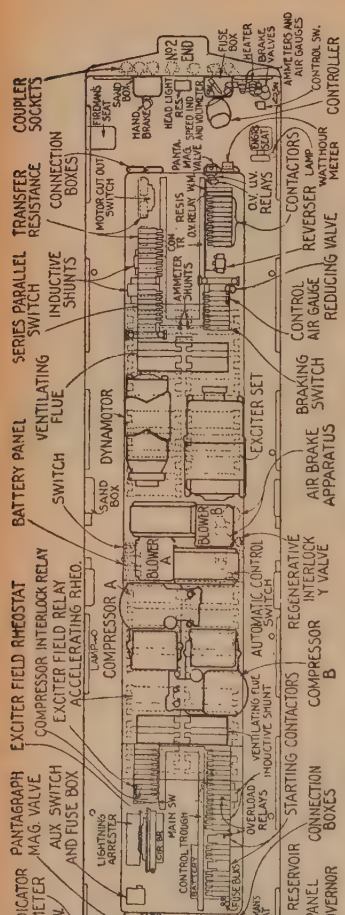


FIG. 6,163—General Electric 150 ton, 3,000 volt *d.c.* locomotive for the Mexican railway. Diagram showing location of apparatus.

Ques. How are locomotives designed for both overhead wire and third rail operation?

Ans. The locomotives contain, in addition to the step down transformer, a motor generator set which converts the *a. c.* to *d. c.* for the motors.

When operating on third rail the pantagraphs or upper contact shoes, are drawn down and the inside equipment disconnected so that only the motors are in circuit and get their current from the third rail.

The controlling devices for starting and speed acceleration are of the electro-pneumatic type.

Gear Ratio.—A single size of motor is suitable for a variety of service and is adapted to meeting different conditions by using different gears to connect the motor shaft to the car axle. In order that gears may mesh properly, the distance between

centers of the gear and the pinion must be constant. The center of the pinion coincides with the center of the motor shaft and the gear center with that of the axle. Hence, for any motor, the gear center distance is fixed, since the axle runs in bearings carried on the motor frame between the axle brackets and axle caps.

In laying out gears for a fixed center distance SA, fig. 6,169, this center distance is divided into two parts such that BA, divided by SB, gives the speed reduction desired.

Exomple.—If a speed reduction of 4.6 to 1, be required, BA, is taken 4.6 times as long as SB. Then two circles are drawn with S and A, as centers

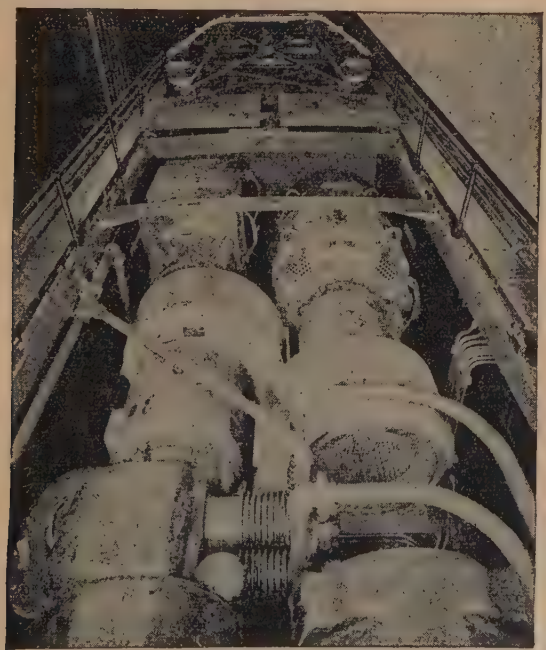
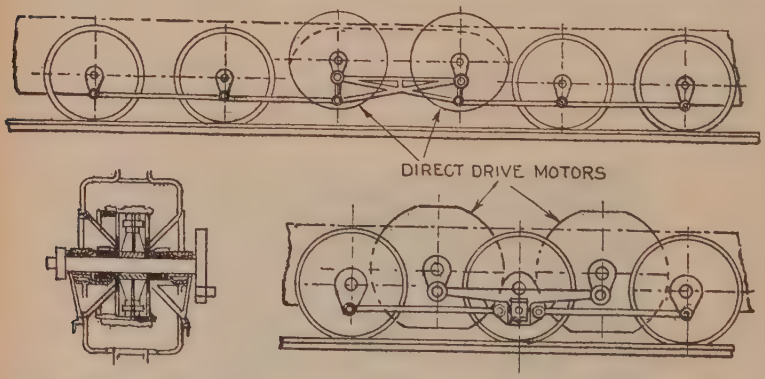


FIG. 6,164.—Auxiliary machinery compartment of General Electric 150 ton, 3,000 volt *d.c.* locomotive.

and SB, and BA, as radii. The circumferences of these circles are of course in the same ratio as their radii, BA, and SB, that is, 4.6 to 1. These circles are known as the pitch circles of the gear and pinion respectively, and the teeth are laid out around these circles. To mesh properly, the distance between centers of adjacent teeth measured along the pitch circles must be the same; so the number of teeth in the gear will be 4.6 times the number of teeth in the pinion. It is evident then that the ratios of radii, diameters and circumferences of the pitch circles, and number of teeth of



FIGS. 6,165 to 6,167.—New York, New Haven and Hartford motor mountings.

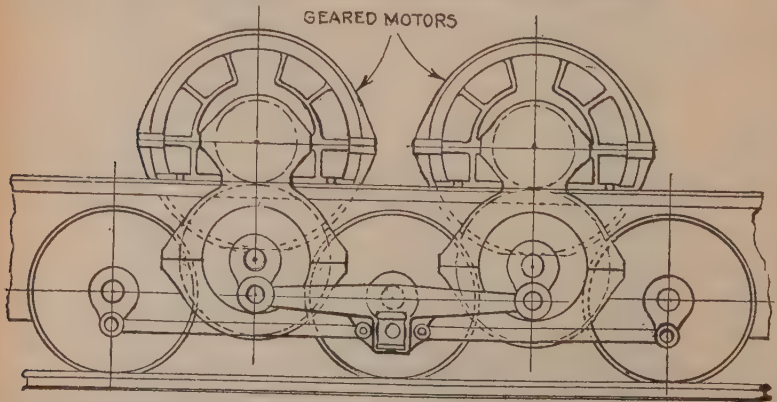


FIG. 6,168.—Method of mounting locomotive motors with both gears and connecting rods The drive is through a form of Scotch yoke and side rods as shown.

gear and pinion are all the same and measure the amount of speed reduction from armature shaft to car axle.

For convenience the gear ratio is customarily expressed by *giving the number of teeth in gear and pinion.*

To determine the size and strength of the teeth used, the pitch of the teeth must be known. There are two common ways of expressing pitch. The distance between adjacent teeth measured along the pitch circle is known as the circumferential pitch and of course is equal to the circumference of the pitch circle divided by the number of teeth.

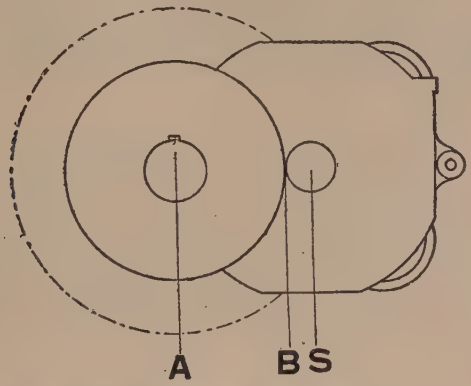


FIG. 6,169.—Diagram for laying out locomotive motor gears.

The more usual and convenient form is *to give the number of teeth per inch of pitch circle diameter* and is called diametral pitch.

In the example cited, assume that the gear center distance SA, is 14 in. and that the diametral pitch is 3. Then SB, is 2.5 in. BA, is 11.5 in.; the diameter of the pitch circle of the pinion is 5 in. and that of the gear is 23 in.; the number of teeth in the pinion is 15 and in the gear 69.

The sum of the diameters of gear and pinion is *twice the gear center distance and is therefore constant.*

Then as long as the pitch and gear center distances are constant, the total number of teeth in gear and pinion is constant irrespective of gear

FIG. 6,170.—General Electric 150 ton, 3,000 volt *d.c.* locomotive. ***It is*** of the twin geared, articulated truck type. A single cab is mounted on two equalizer frames which, in turn, are carried upon three two axle articulated trucks. A motor is geared directly to each axle with twin, cushion type gears. The six motors, with which each locomotive is equipped, are of the box frame, twin geared commutating pole, railway type with forced ventilation. They are designed to operate two in series on a 3,000 volt circuit, or 1,500 volts per commutator. The windings are therefore insulated for 3,000 volts to ground. An 18 tooth steel pinion is mounted on each end of the armature shaft, and these mesh with 90 tooth cushion type gears on the axle. An unusual feature of the design of this locomotive is the provision for removing the motor, wheels, or axle from any of the trucks without removing the cab. By disconnecting the motor leads and jacking up the motor and the side frames, the wheels and axle and finally the motor can be lowered into a pit. The power for the operation of the auxiliaries is provided by a 3,000-1,500 volt dynamotor which carries a 4 *k.w.* 65 volt control dynamo mounted on a shaft extension. The two blower motors and the two compressor motors are normally operated in series across the 3,000 volt supply, using the mid-point of the dynamotor for equalization. This scheme allows the operation of the compressors and blowers directly from the trolley in case of failure of the dynamotor, and of one compressor or blower in case of the failure of the other machine. An exciter set, used for regeneration, is driven by a 1,500 volt motor operated from the 1,500 volt dynamotor bus. If it be not necessary to operate the blowers at maximum capacity, they can also be operated on the 1,500 volt circuit by connecting them in series. The control dynamo supplies current at 65 volts for lights, head lights, foot warmers, and control circuits, and for charging the storage battery.

FIG. 6,171.—General Electric running gear of 150 ton, 3,000 volt *d.c.* articulated type locomotive.

ratio. This fact makes it very easy to find the number of teeth in the gear and the pinion for changing the gear ratio. In this case, for 14 inch gear centers and 3 pitch, the total number of teeth is 84. Assume a gear reduction of 3.2 is desired; that is, the number of gear teeth is to be 3.2 times the number of pinion teeth. The total number of teeth will be $(3.2 + 1) = 4.2$ times the number of pinion teeth which will be $84 \div 4.2 = 20$. The gear will have $3.2 \times 20 = 64$ teeth and the ratio will be 20:64.

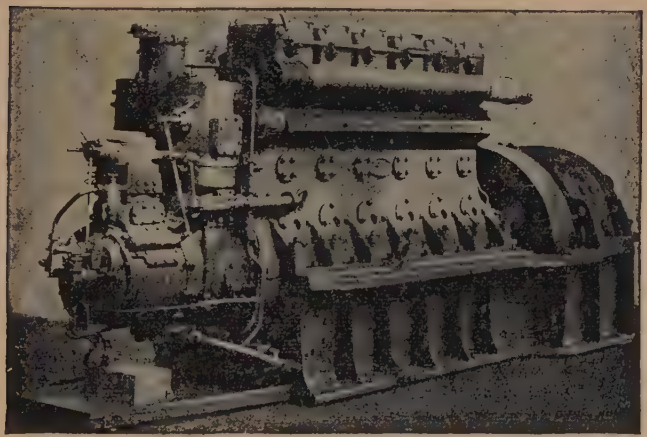


FIG. 6,172.—Westinghouse intake side of 300 *h.p.* oil engine for oil electric locomotive. The four stroke cycle engine is arranged to idle at 300 *r.p.m.* and to deliver full output at 800 *r.p.m.* The speed characteristics are such as to effect a reduction in weight per *h.p.* The engine, including fly wheel weighs approximately 7,000 lb. or 23.3 lb. per *h.p.* The main dynamo is a 750 volt, 210 *k.w.* variable voltage *d.c.* machine receiving field excitation from a 64 volt, 5.3 *k.w.* auxiliary dynamo. The auxiliary dynamo armature is pressed on an extension of the dynamo shaft while the stator is bolted to the main dynamo bracket and is easily removable. The commutator end of the armature is carried on a sleeve type bearing while the engine end of the armature is bolted to the fly wheel and is carried by a double bearing in the engine. The principal function of the main dynamo is that of supplying power to the traction motors. It is also used as the starting motor for starting the engine, receiving its power from the 64 volt, 204 ampere hour storage battery. Lastly, it serves to charge the battery and supplies power for operating the compressors and auxiliaries at engine idling speed of 300 *r.p.m.* The auxiliary dynamo besides supplying power for excitation of the field of the main dynamo, furnishes power for compressor operation and battery charging when the main dynamo is running at higher than idling speeds. The motor equipment consists of four locomotive type traction motors, 16:61 gear ratio and having an hourly rating of 146 amperes at 600 volts or a continuous rating of 85 amperes at 300 volts. They are self ventilated. This type of motor was designed for a high tractive force at low speed for trolley type locomotive service and is an ideal application for switching service with an oil electric locomotive.

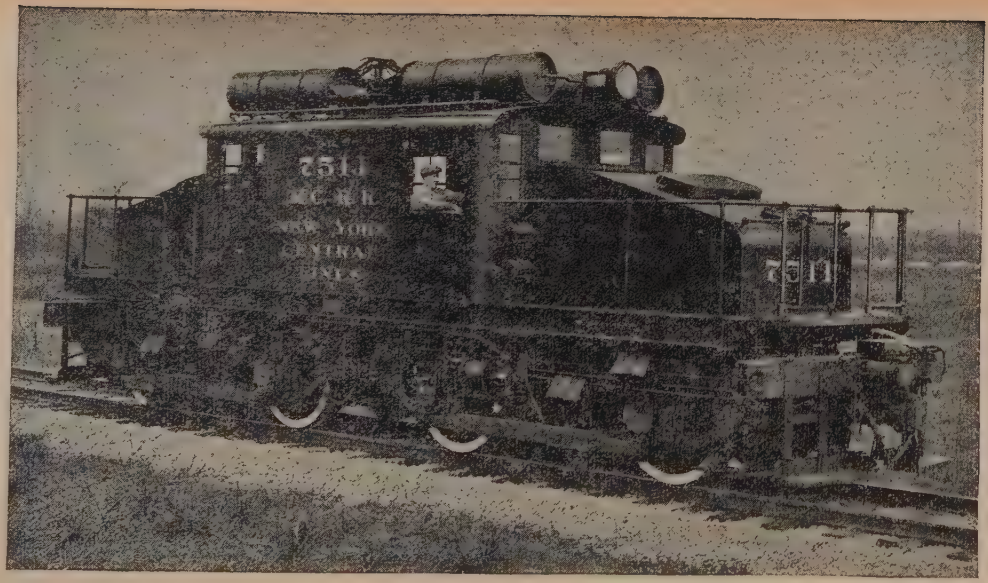


FIG. 6,173.—General Electric 120 ton, 600 volt *d.c.* locomotive.

Locomotive Selection.—There are many factors, some of them seemingly unimportant, that must be considered in selecting an electric locomotive and its equipment for a given service. It is possible, with little difficulty, to choose a motor equipment that will be more than large enough for the work. However, to determine the proper combination of weight, horse power and speed to accomplish the tonnage movement

desired over a given profile with highest efficiency, low maintenance and minimum first cost, requires careful study of all operating conditions as well as definite knowledge as to what work can actually be performed with certain electric motive power equipment under the specific conditions encountered.

Safe and sane operating conditions for the train crew, rolling equipment and freight are of course the first consideration in such computations.

The fundamental law applying to train movement by electric locomotive is that in pulling a trailing load of cars weighing a certain number of tons, the motors must be capable of exerting a certain variable number of pounds tractive effort or pulling force at the driving wheels in order to overcome the forces tending to retard the movement of the train.

From this it is evident that the friction between the rails and wheels is a function of the capacity of the locomotive to move tonnage. The maximum tractive effort rating of Baldwin-Westinghouse standard electric locomotives is 25% of the weight on the driving axles. With clean, dry rail, the coefficient of friction between wheels and rail may be as high as .35 giving an instantaneous tractive effort of 35% of the weight on drivers. If the pull required at the drawbar plus the locomotive frictional resistance exceed this number of pounds and the motors have torque in excess of this value, the wheels will slip and not permit the train to start.

Motor capacity or output is *largely a matter of temperatures.*

A relatively small motor can exert a comparatively enormous tractive effort for an instant, but the heat developed in its windings will be so great that it will burn up if operated continuously. A motor equipment may be large enough to haul a train at schedule speed, over a long stretch of level track and remain at a safe temperature, but, if grades or long sharp curves are encountered the temperature of the motor may rise to a dangerous degree.

Much more power is required to bring a train up to speed than is required to run it after that speed is attained.

Motors for Mine Locomotives.—These are similar in many respects to motors for street railways.

Both of these types are *d.c.* motors and commonly transmit power to the driving wheels through single reduction gearing. The method of mounting is also similar, one side of the motor being suspended from the axle by means of axle bearings, and the other side by an attachment to the truck framing. There are, however, a number of requirements affecting the design of mine locomotive motors which serve to separate them as a group from other forms of traction motors. These requirements are of course a result of the kind of work which the mine locomotive must do and the conditions under which it must be done. Comparatively few years of motor evolution have established the features which enable one to recognize a mine locomotive motor even if seen alone and not as a part of the locomotive.

FIG. 6,174.—A mine locomotive with side frames removed to show position of motors.

Having in mind the space limitations, the motor designer has the problem of so proportioning the parts as to obtain a maximum torque from a frame of certain dimensions.

The active electrical parts must be proportioned, however, with due regard to clearances between revolving and stationary parts, mechanical strength, access to brush-holders, correct lubrication, etc.

A careful distinction should be made between motor torque (or tractive effort) and horse power.

If a locomotive be equipped with motors that develop a certain torque at the armature shaft, the locomotive will have a corresponding tractive effort developed at the wheels. In other words, the locomotive will pull a certain number of cars of coal or ore. This pulling ability represents the torque which the designer has been able to get out of a motor of given frame

dimensions and is practically independent of horse power. The horse power is the result of both this pulling ability and the speed at which the pulling is done as shown in the familiar formula:

$$\text{horse power} = \frac{\text{torque} \times r.p.m.}{520}$$

The error is often made of assuming that, of two locomotives otherwise the same, the one having motors of higher horse power will pull more loaded cars. It is true that five horses may be able to pull a load that four cannot, but it does not follow that a locomotive equipped with 50 horse power motors can pull more cars of coal than one equipped with 40 horse power

FIG. 6,175.—Typical mine locomotive motor.

motors. The difference is that all horses pull at about the same speed while electric motors may be designed for a wide variety of speeds. Knowing the torque that may be obtained from a given motor volume, the correct speed is dependent upon the desirable locomotive haulage speed.

Locomotives used for gathering cars within the mine may operate at speeds as low as four to six miles per hour, while main haulage locomotives have a most desirable speed at eight to twelve miles per hour. The tendency is toward lower speeds than formerly for gathering locomotives, and for higher speeds for main haulage.

The standard voltages for trolley type mine locomotives are 250 and 500 volts.

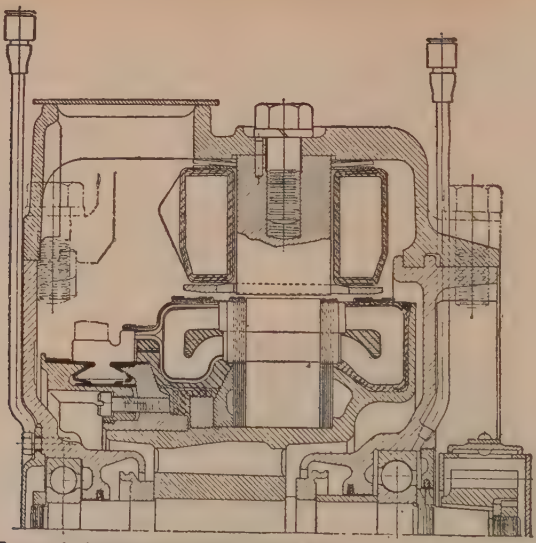


FIG. 6,176.—Top half of extremely narrow gauge motor.

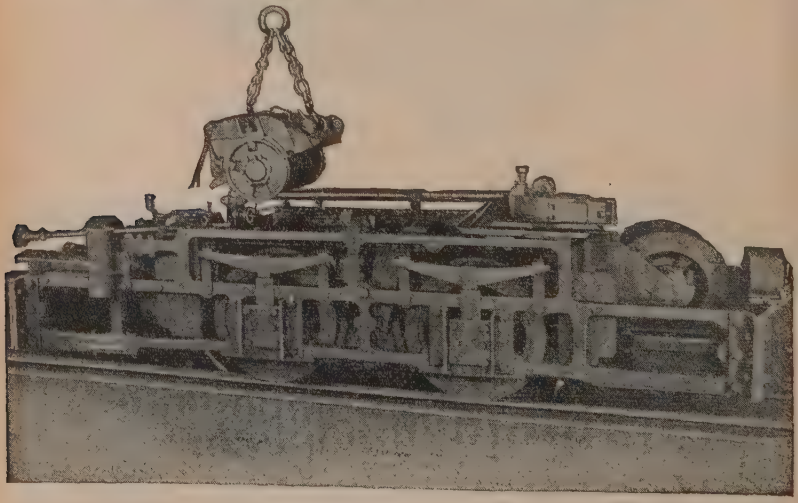


FIG. 6,177.—Method of removing top half of split frame motor and armature.

The 500 volt trolley has proved dangerous due to workmen coming in contact with it. The 250 volt standard is rapidly coming into more general use, while 500 volts is seldom used in a mine.

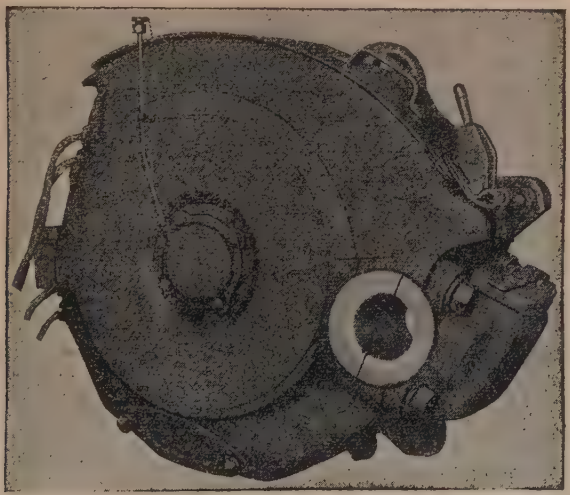


FIG. 6,178.—Mine locomotive motor for use on 18 inch track.

NOTE.—*Several states* have passed legislation prohibiting the installation of a 500-volt trolley in new mines. For storage battery locomotives 80 volts is usual, 48 cells of lead or 80 to 88 cells of Edison battery. The mine motor, along with other types of electric motors, has become standardized in the use of commutating pole windings for voltages of 250 and above. The 80-volt motors for operation from storage batteries are usually of the non-commutating pole type, as commutating poles are not necessary at this voltage to obtain sparkless commutation.

NOTE.—***Flame proof construction.*** The explosion tested or permissible construction has resulted from the necessity for motors that can be safely operated in the presence of explosive gases or coal dust. The U. S. Bureau of Mines has established a schedule of construction details and tests which must be met in order to obtain its approval of the apparatus as being permissible for operation in gaseous mines. The final tests which are made on new motors by the Bureau definitely prove that an explosion of gas inside will not cause an explosion of gases surrounding the motor. The fully permissible locomotives are naturally limited to the storage battery type. The trolley locomotive is eliminated due to the sparking between trolley wheel and trolley. Some operators not favorable to storage battery locomotives have greatly minimized the danger of explosions by using locomotives equipped with explosion tested motors and control and obtaining power through a cable reel and cable. This cable is hooked to a trolley in the main entry where the ventilation is good and the probability of explosive gases is small.

Accordingly, the duty on the motor is very severe at starting. It is apparent then, that in order to select the most suitable motor equipment for a given service, the track, grade and traffic conditions must be fully understood.

It is also obvious that the motor equipment must be capable of exerting a tractive effort for short periods approaching the tractive limits of the complete locomotive mechanically without serious temperature rise if the locomotive is to be a successful application. These facts indicate the danger that may arise if a locomotive be over ballasted. The weight of a locomotive for a certain service may be limited also by the strength of bridges and the weight of rail.

The maximum current which the locomotive can safely take from the sub-stations, the probable tonnage to be handled daily

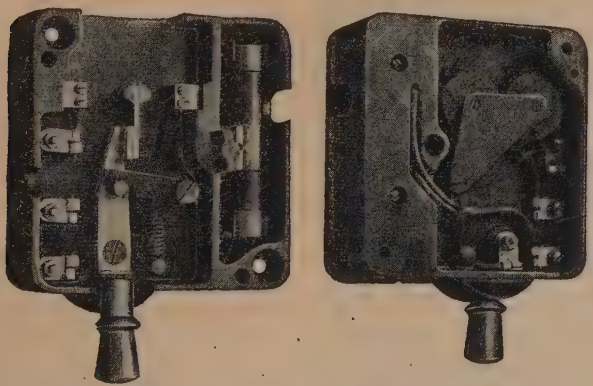
FIG. 6,179.—General Electric Diesel electric locomotive. Built essentially for switching service, the 4-4 wheel locomotive here shown mounts a 300 *h.p.* Ingersoll-Rand airless injection oil engine direct connected to a 200 *k.w.*, *d.c.* General Electric dynamo, which furnishes current to four motors of the same make geared to each of the four axles. The under frame was built by the American Locomotive Co. of rolled steel channels carrying two 4 wheel trucks of the pedestal type. Carried on board the locomotive are also the following apparatus: 2 G. E. motor driven air compressors; 1 G. E. automatic air brake schedule; 1 straight air brake schedule; 1 gasoline air starting set; 5 contact switches; 1 storage battery set; 1 charging relay; 2 fuel oil tanks; 2 cooling water tanks; 1 cab, lights, head lights, etc.

and at what points it will originate and be delivered, are other factors which affect the proper selection of locomotives.

The four major service requirements of a locomotive may be summarized as follows:

1. It must have sufficient weight on drivers to start the heaviest train on the maximum grade at reasonable adhesion.

2. It must have sufficient continuous motor capacity to avoid overheating in continuous service.



FIGS. 6,180 and 6,181.—Westinghouse locomotive control and reset switch.

3. It must have sufficient overload capacity to successfully meet short time load demands imposed by starting or running train on grades.

4. It must have proper speed characteristics to suit the traffic requirements. Slow speed operation reduces power demands on sub-stations, but may interfere with passenger service or not be sufficiently fast for express freight service.

Locomotive Control Equipment.—As an example of control the standard unit switch system as used on Baldwin Westinghouse locomotives is here described. This type of control has

the following advantages as applied to locomotive installations and operation:

1. Hand acceleration is particularly necessary in switching operations for safety reasons in order that the engineer may have complete control of the locomotive speed at all times. The unit switch control is well adapted for, and is always applied to, locomotives arranged for hand acceleration.

FIG. 6,182.—Westinghouse overload relay for locomotive.

2. The contact pressure of the unit switches is independent of the line voltage. This feature is useful in handling heavy seasonal freight on parts of a railway system where voltage may be low.

3. Ample protection is provided against excessively heavy overloads, grounds, short circuits, surges in the contact line and lightning.

4. Two or more connected locomotives may be operated from any one master controller.

Main Circuit Switches.—The various main circuit connections are made by unit switches operating by compressed air supplied by the air brake system.

The admission of air to the unit switches is controlled by electro-pneumatic valves. These valves are actuated by current from a low voltage control circuit carried through a train line from the master controller. This low voltage control circuit is obtained by tapping from points on the control resistor, which is connected between trolley and ground.

Each switch is closed against a powerful spring, by a piston actuated by compressed air when its control circuit is energized. The switch will be opened quickly by this spring when the air is released. The movement of the switch, either opening or closing, is rapid and positive, and heavy contact pressure is obtained.

Reverser.—The movement of a locomotive is directed either forward or backward by means of an electro-pneumatically operated reverser.

The reverser consists of a number of stationary fingers mounted on a rigid base and pressing upon one or the other of two sets of contacts which are mounted on a rotating drum.

The lever on the master controller controls the rotation of the drum to place the correct set of contacts for the direction of movement desired, in contact with the stationary pressure fingers.

FIG. 6,183.—Westinghouse electro-pneumatically operated reverser for locomotives.

The reverser is so interlocked that it cannot be operated unless the controller handle be in the *off* position.

Main Fuse Box.—To protect the locomotive equipment from grounds or short circuits, a fuse is connected in the main circuit next to the trolley.

An overload relay is provided with its operating coil connected in the main circuit ahead of the line switch. This relay, adjustable over a wide range in current values, will cause the main circuit to be opened when a predetermined limit of current has been reached.

Grid Resistors.—The grid resistors consist of the required number of 8 in. three point suspension cast iron grids, arranged in a suitable number of frames.

The grids comprising each frame are held together between sheet steel end plates by three mica insulated tie rods arranged at the three points of an equilateral triangle, which gives a very solid and substantial construction.

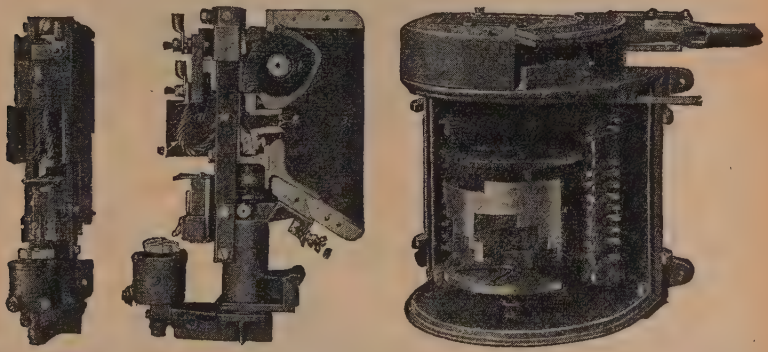
FIG. 6,184.—The engineer's locomotive operating equipment.

Master Controller.—The control circuits for operating the unit switches and the reverser are established by means of the master controller levers. One lever is provided for notching up or accelerating the locomotive and another lever for reversing the direction of movement as explained under the heading *Reverser*.

The reversing lever is interlocked mechanically with the operating handle, so that it cannot be thrown to another position unless the main drum is in the *off* position.

Sixteen notching positions are provided on the master controller. A master controller is located in each end of the cab for double end operation.

Meters, Gauges, Etc.—An instrument board is located within easy vision from the engineer's position.



FIGS. 6,185 and 6,186.—Westinghouse side and front of a typical main control circuit unit switch for locomotive. ***The parts are:*** 1, blowout coil; 2, contacts; 3, arc box side; 4, upper arc block; 5, lower arc block; 6, arc box latch; 7, terminal board; 8, shunt; 9, magnet valve; 10, mounting bar; 11, barrier.

FIG. 6,187 —Locomotive master controller with cover removed.

An ammeter connected in the main circuit, air gauges, and a volt meter are mounted on this board, and each is well illuminated from a central light by reflectors which also shield the light from the direct vision of the operator. An instrument board is installed in each end of the cab.

The control equipment includes also, all necessary auxiliary apparatus such as motor cut out switch, main switch, lighting switches and lightning arresters.

Locomotive Air Brake Equipment.—This consists of double air compressor units to provide an ample and reliable air supply, an automatic governor which controls the operation of the

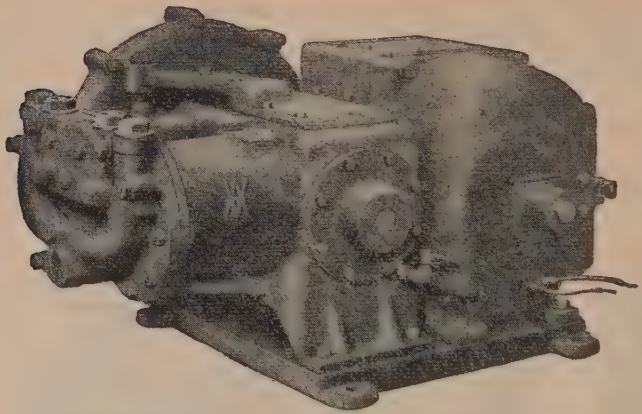


FIG. 6,188.—Westinghouse motor driven air compressor for locomotive.

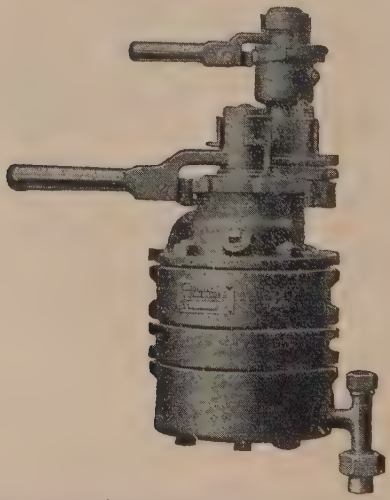


FIG. 6,189.—Westinghouse operator's brake valve. The upper lever is for locomotive brakes only. The lower lever operates the automatic brakes. The air brake has two functions, namely, to stop the train in the shortest possible time, and to insure smoothness and reliability in train handling. To obtain these, the equipment is a combined automatic and independent brake, allowing the locomotive brakes to be controlled independently of, or in conjunction with, the train brakes.

compressors between predetermined maximum and minimum pressures, reservoirs with sufficient storage capacity, double end brake valves with an independent and automatic position, a distributing valve and the brake cylinders.

Severe service demands double air compressor units to provide sufficient air for braking and other purposes. The control of the compressors is so arranged through a governor synchronizing system that each unit will carry its share of the load, both when operating as a single cab locomotive or with two cabs in multiple. The compressors may also be operated independently when necessary.

TEST QUESTIONS

1. *Give a classification of electric locomotives.*
2. *What types of motor are used on electric locomotives?*
3. *What is the advantage of inter-pole motors?*
4. *How is the field arranged in a field controlled motor?*
5. *How is the voltage reduced in electric locomotives from high tension to low tension for the motors?*
6. *How are locomotives designed for both overhead wire and third rail operation?*
7. *What types of drive are used between motor and power wheel axle?*
8. *Describe the method of laying out gears.*
9. *How is a gear ratio usually expressed?*
10. *What are the points relating to locomotive selection?*
11. *Give comparison of the power required for train operation, in accelerating and at constant speed.*

12. *What are the features of mine locomotives?*
13. *Describe a Diesel electric locomotive.*
14. *Describe at length the locomotive control equipment.*

CHAPTER 134

Current Collecting Devices

Classification.—The various electric traction systems in successful use as distinguished by the mechanical means provided and special methods adopted for supplying current to the motors are, as already mentioned, divided into four classes:

FIGS. 6,190 and 6,191.—Trolley wheels. Fig. 6,190, Ideal trolley wheel; fig. 6,191, Union standard trolley wheel. The trolley wheel must not be hard enough to wear the wire unduly, it must not be soft enough itself to wear out readily, and it must have maximum conductivity. Union standard trolley wheels are made of phosphor bronze, while the Ideal trolley wheel is made with a forged copper center on either side of which steel flanges are pressed.

1. Overhead trolley system;
2. Pantagraph system;
3. Third rail system;
4. Underground rail or conduit system.

The Overhead Trolley System.—In this arrangement which is largely used in towns and cities, the current for the motors

FIGS. 6,192 and 6,193.—Ohio Brass trolley wheel and harp.

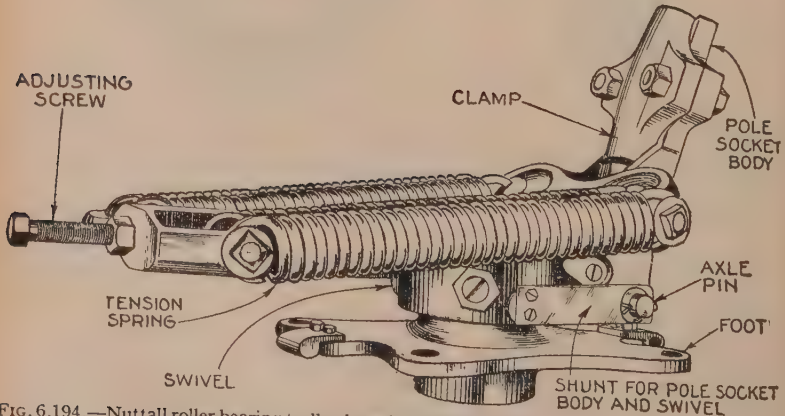


FIG. 6,194.—Nuttall roller bearing trolley base for interurban or city service. This base is supplied with copper shunts which connect the pole socket axle pin to the swivel casting and obviate the necessity of carrying current through the bearing. Its wheel pressure increases as the pole approaches the perpendicular.

is taken from an overhead wire by means of a "trolley" with grooved wheels, which is held up against the wire by a flexible pole. The wires from the contact wheels pass down the pole to the car controller and thence to the motor, the return circuit usually being through the rails.

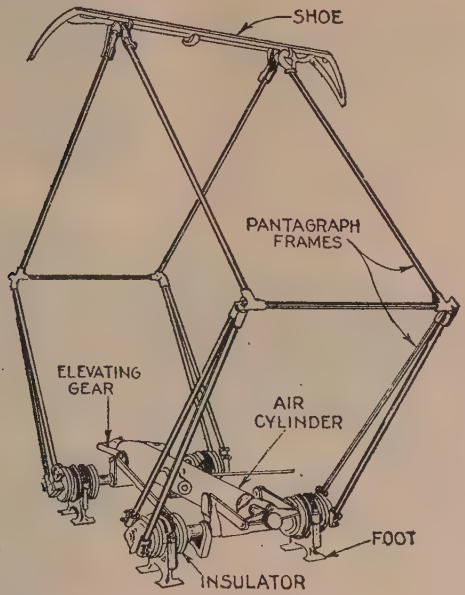
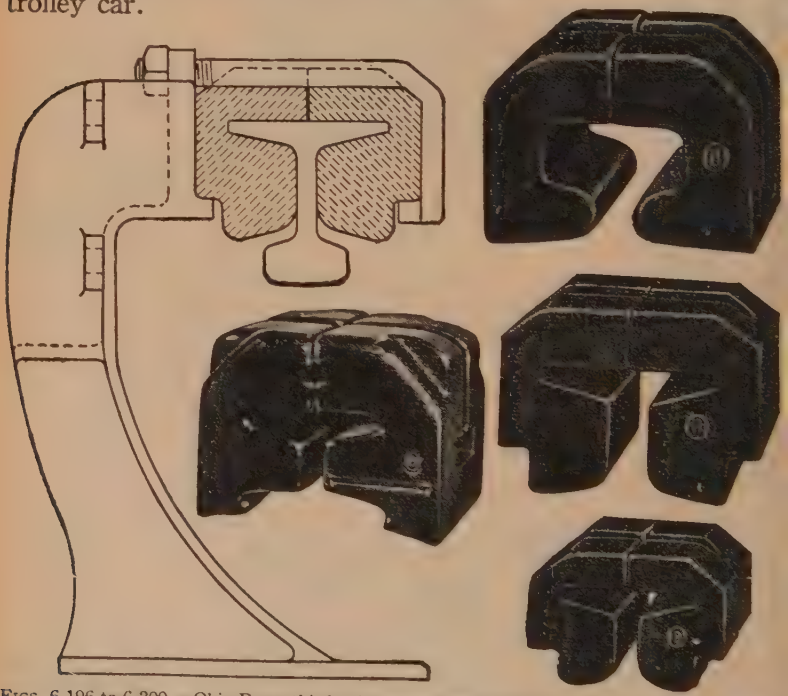


FIG. 6,195.—Pantagraph, single shoe type.

Pantagraph System.—This is a *form of trolley used in high speed electric traction*. A broad contact shoe formed of conducting material is supported by jointed elbows resembling a pantagraph carried on springs. The trolley is raised and lowered by compressed air. The top of contact member of the pantagraph slides along the overhead wire and is used where the voltage is high; for instance, 1,100 volts or over.

The Third Rail System.—In this system a rail called the "third rail" is laid outside the track rails. The current is taken by means of a suitable contact shoe which slides along the rail, and the car is controlled by the motorman as in the case of a trolley car.



FIGS. 6,196 to 6,200.—Ohio Brass third rail support and insulator, for under contact operation. This is used in open roadways where snows may be heavy and it is necessary to have greater distance between the live rail and the ground. The shoe slides under the rail instead of on top of it as in subways or other protected places.

The third rail contact shoe is a projecting foot or shoe at the base of the car, supported by springs and which presses against and slides upon a rail energized to give the current.

In the operation of trains as in subways or on elevated roads where the consumption of current is considerably heavier than for single cars, third rails displace the trolley wires for conveying the current to the motors.

Ques. What are third rails?

Ans. Track rails set on insulators alongside of tracks to provide a means for supplying large quantities of current to trains.

Ques. How is this done?

Ans. By means of shoes extending from the bottom of the cars which slide along the top or underside of the rails.

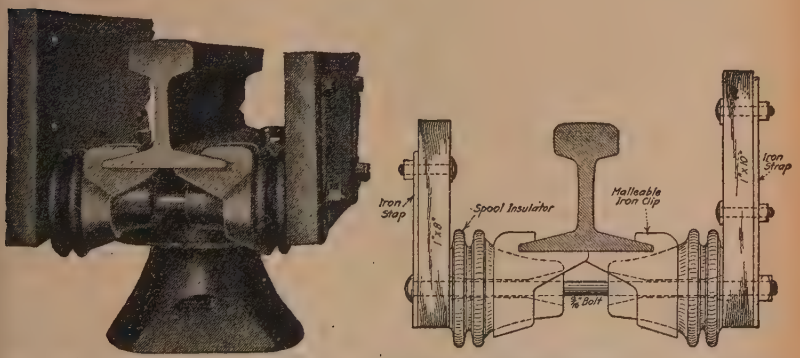


FIG. 6,201 and 6,202.—Third rail support and insulator for higher than 600 volt operation and protection boards at the side for protection against side contact.

Third rails are installed in various ways as regards protection against contact and for workmen; and these ways depend upon the roadway, the type of shoe used, and the amount of protection required.

For top contact shoe, side boards are used as shown in fig. 6,201; for sliding contact shoe, a top covering with sufficient spacing for the shoe to come in at the side is used; for under-contact shoe, a metal insulator holder covers the rail and offers the necessary protection.

Ques. How are third rail sections made continuous electrically?

Ans. Either by welding the joints or by putting on splice plates, as on track rails, and copper bonds across them.

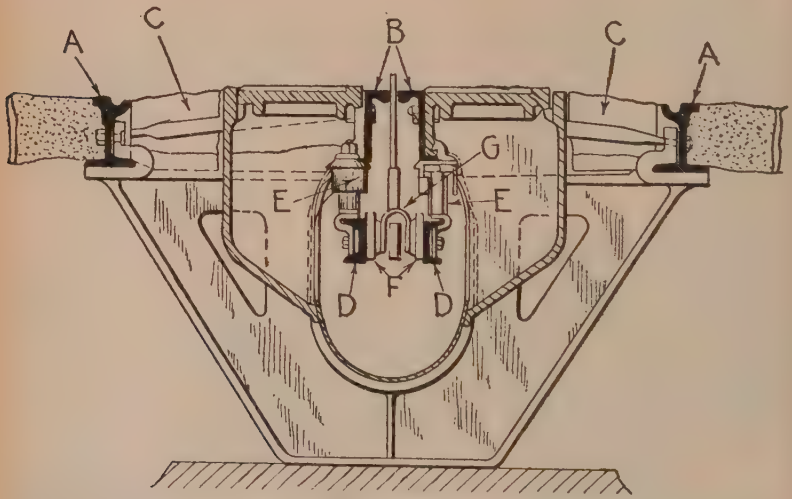


FIG. 6,203.—Yoke construction for conduit or underground trolley, as installed on Metropolitan Railways, New York City. These yokes were placed 5 feet apart in an excavation made through the street. The track rails A, A, and the slot rails, B, B, were then laid on the yokes, and the ties C, C, inserted. The whole structure was then blocked up, surfaced and lined, and constituted the track construction. The conductors consist of two channel beams, D, D, placed 6 inches apart and supported by insulators E, E, at each yoke. The contact rail joints are bonded in a manner somewhat similar to ordinary rail bonding, and form a complete metallic circuit having a pressure of 500 volts between the conductors. The current from these conductors passes through the slot or opening between the slot rails and extends into the conduit to a distance sufficient to bring the plow contacts or shoes F, against the conductors. The spring G, tends to keep the shoes normally about 8 inches apart, so that when they are pressed into the 6 inch space between the conductors, they maintain a firm sliding contact with the latter. Hand holes provided with iron covers are placed about 15 feet apart directly over the insulators. The manholes are placed about 150 feet apart, and usually between the tracks. Arrangements are made at these points to drain the conduit into the sewers. The bottom of the conduit is given a minimum grade of 2 inches to 100 feet, so as to insure proper drainage on sections of level track. The contact rails are treated like a double trolley wire, and the feeders and mains are laid in underground conduits. This system is so expensive to install that its use is limited to only the largest cities where for various reasons the use of the overhead trolley is objectionable and prohibited.

Ques. What are bonds?

Ans. Bonds are copper straps with terminals for carrying the current around the track joints.

Ques. How are they fastened?

Ans. By drilling holes in the rails and compressing the ends or terminals of these copper straps in the holes.

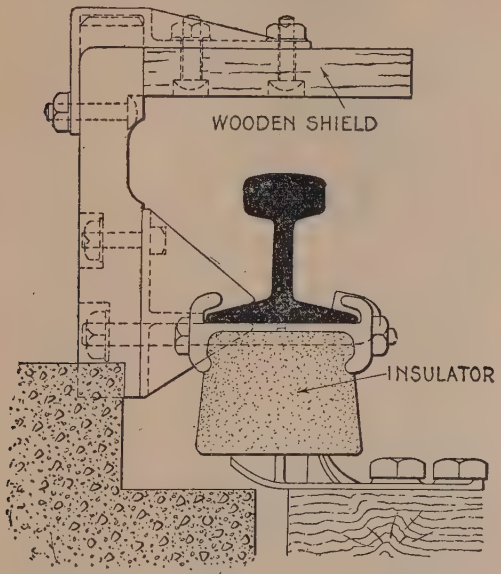
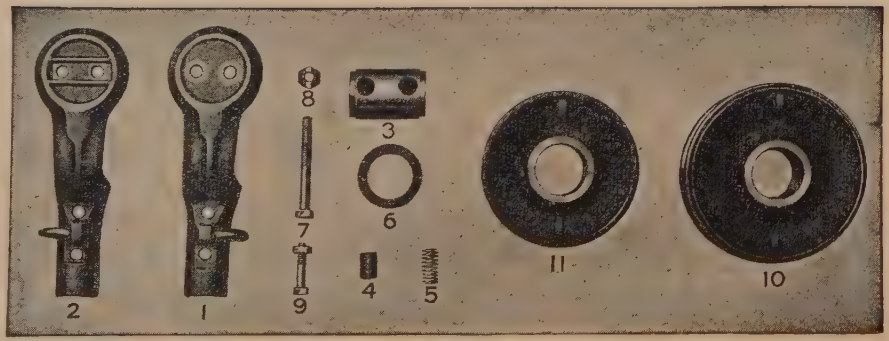


FIG. 6,204.—Cross section showing construction of protected top contact third rail.

The Underground Trolley or Conduit System.—This system is used only in large cities where trolley cars are maintained and poles and overhead wires are not permitted. The construction is extremely high in cost compared with trolley wire installation.



FIGS. 6,205 to 6,215.—Ohio Brass Co. trolley wheel and harp parts. Harp (includes one of 1, one of 2, two of 9). ***The parts are:*** 1, harp casting, right hand (smooth face for axle bolt nuts); 2, harp casting, left hand (ribbed face for axle bolt heads); 3, axle (without plugs or springs); 4, graphite plug (three required per axle); 5, spring for graphite plug (three required per axle); 6, fibre washer (two required per axle); 7, axle bolt, without nut (two required per axle); 8, grip nut, special, for axle bolt (two required per axle); 9, pole attachment bolt with nut (two required per harp); 10, 6 inch trolley wheel; 11, 5 inch trolley wheel.

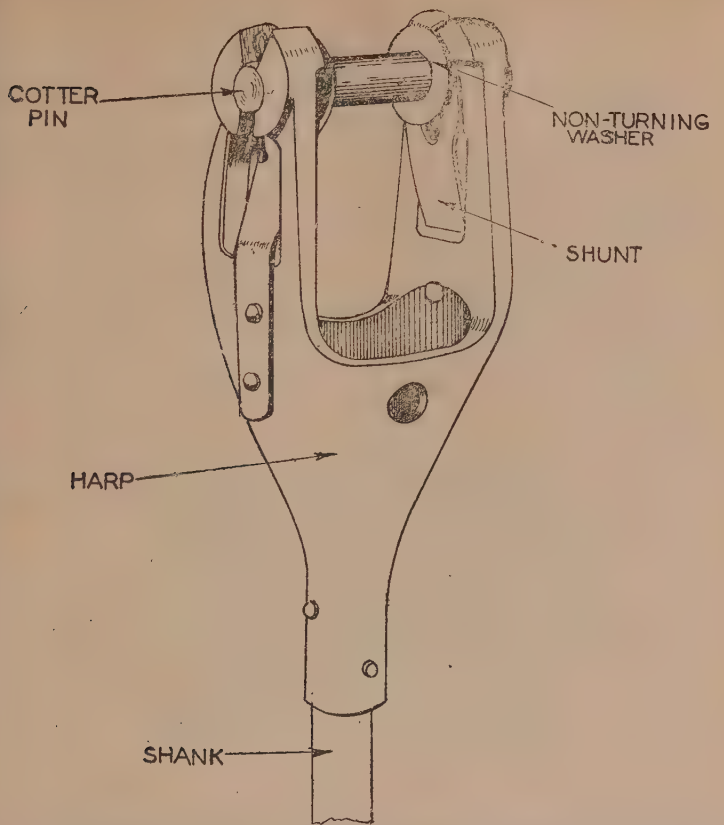


FIG. 6,216.—Typical trolley harp. ***In construction*** a harp is best made of malleable iron as this metal is best adapted for the strenuous overhead service because harps so constructed are strong enough to withstand shocks caused by wheels leaving the wires. Heavy harps place a severe burden on the springs in the trolley base and make the spring action sluggish, but malleable iron harps, because of their light weight, do not retard the function of the springs. Furthermore, there are no sharp corners or projections to catch and tear down overhead. The features of these harps are: 1, Non-turning washer -a lip on the edge of the washer fits down into a slot in the harp and locks the contact washer in place. 2, Phosphor bronze shunt springs--the shunt springs are turned into a slot and riveted to the outside of the harp. The shunt springs do not come in contact with the wheel and consequently there is no friction wear. 3, Axle pin -the axle pin is case hardened The cotter pin which holds it in place is easily accessible and may be removed on the job quickly and without difficulty.

TEST QUESTIONS

1. *Give a classification of the various current collecting devices.*
2. *In what localities is the overhead trolley largely used?*
3. *Describe the overhead trolley.*
4. *What is a pantagraph?*
5. *How is a pantagraph raised or lowered?*
6. *Describe the operation of the pantagraph system.*
7. *What is a "third rail"?*
8. *How is current taken from a third rail?*
9. *Describe several types of third rail mounting.*
10. *Name two methods of shoe contact.*
11. *How are third rail sections made continuous electrically?*
12. *What are bonds?*
13. *Describe the underground trolley or conduit system.*
14. *What are the requirements of a conduit system?*

CHAPTER 135

Railway Control Methods

The control apparatus on a car provides for the correct application of power in starting, for operation "forward" or "backward" for opening the power circuits in order to slow down or stop, and for the protection of the equipment.

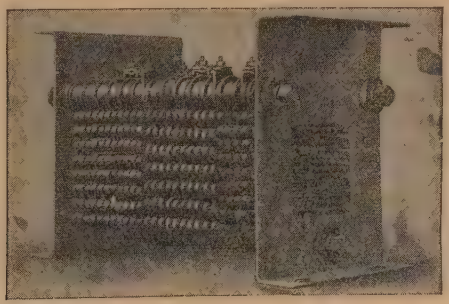


FIG. 6,217.—Westinghouse standard resistor for *d.c.* railway equipment.

If full trolley voltage were applied to the motors at standstill, an enormous current would flow through them and they would develop an immense tractive effort. The result would be disastrous both electrically and mechanically; in fact, satisfactory operation would be impossible.

The control, therefore, includes electrical resistance, made up in the form of grids mounted in one or more frames, fig.

6,217, which is connected in series with the motors during the starting.

This resistor is provided with taps so that the amount of resistance in the circuit may be gradually reduced from the maximum at the instant of starting until it is finally all cut out of circuit and the motors are receiving full voltage.

The various connections are made through a controller, each step at which a connection is changed being known as a "point" or "notch" on the controller.

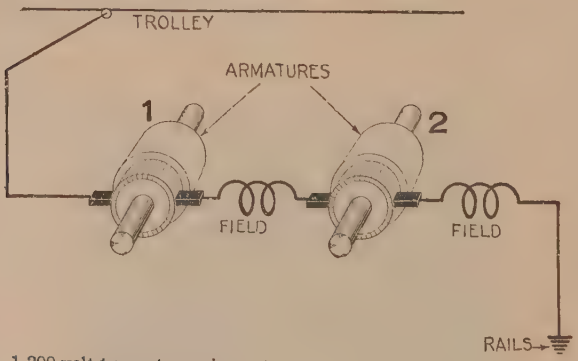


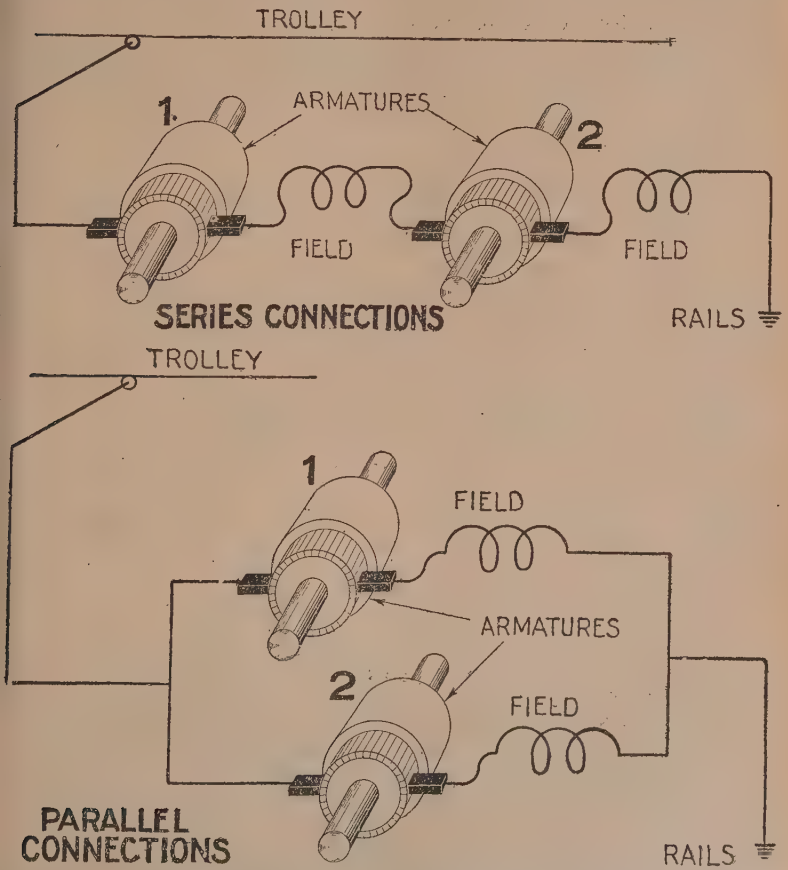
FIG. 6,218.—1,200 volt *two motor* equipment.

As a controller has comparatively few points, the voltage applied to the motors is increased gradually by steps, instead of continuously, which would be the ideal method, if practicable. Hence, the current and consequently the tractive effort of the motors vary during the "notching up" process.

Controllers and resistors are designed so that with ordinary handling the voltage steps will be fairly regular and the variation of current in the motors limited so that smooth starting results.

Fig. 6,221 shows approximately how the current CC^1 and the voltage at the motors VV^1 change as the controller is operated.

All modern railway equipments include an even number of motors.



FIGS. 6,219 and 6,220.—Series, and parallel hook ups for 600 volt *two motor* equipment.

With one motor equipments and where only two motors are used and are connected in series so that they may be operated from the trolley at twice the motor voltage (such as two 600 volt motors in series on a 1,200 volt trolley), fig. 6,219 and 6,220, indicate the starting conditions and proportion of rheostatic loss. Only a small number of such car equipments are in use and their field is very limited. The platform controllers used with them are known as R type or rheostatic controllers. Hence, it may be said that the majority of car equipments may have the motors individually connected in series or parallel with each other, or the motors may be grouped two in series or two in parallel and the groups connected in series and

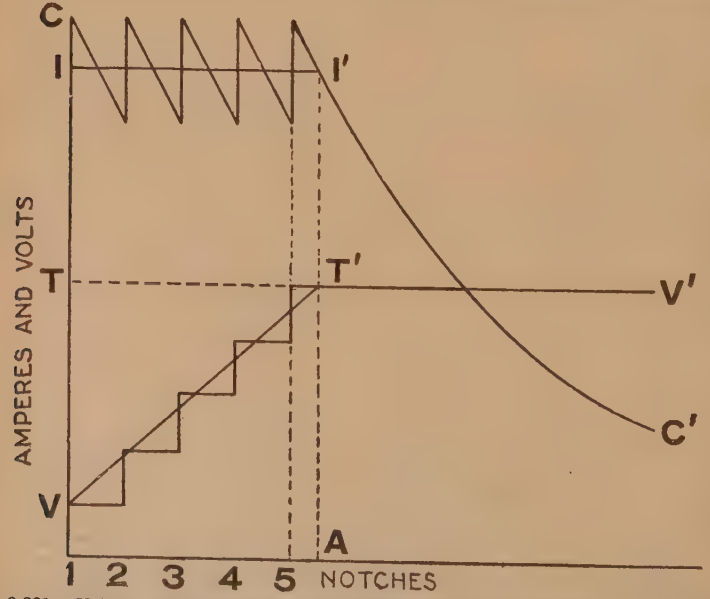


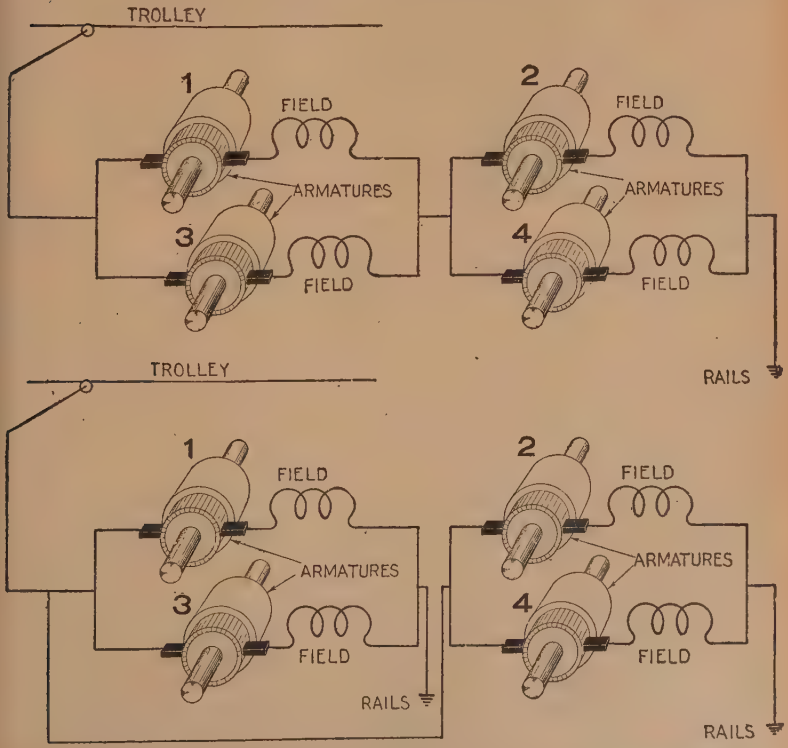
FIG. 6,221.—Volt and ampere diagram for various positions of the controller. For simplicity in calculation the voltage is assumed to vary continuously as indicated by the line, VT', and the current is assumed constant during notching as shown by the line II'. Although the voltage applied to the motors themselves varies from V to T', the voltage at which current is taken from the trolley is constant at TT'. The difference between trolley and motor voltages is taken up by the resistor. In the diagram, the area TT'A1, is a measure of the total energy taken from the trolley while notching up the controller and the area, VT'A1, measures the portion of this total energy received by the motors. The area VTT', represents that portion of the total energy which is absorbed in the resistor and is a total loss, as it does no useful work but is dissipated by the resistor as heat. In the figure this resistance loss is nearly one half of the total energy taken from the trolley during the starting period.

parallel for starting. The purpose of such series parallel arrangements is to reduce the rheostatic loss below the amount indicated by fig. 6,221.

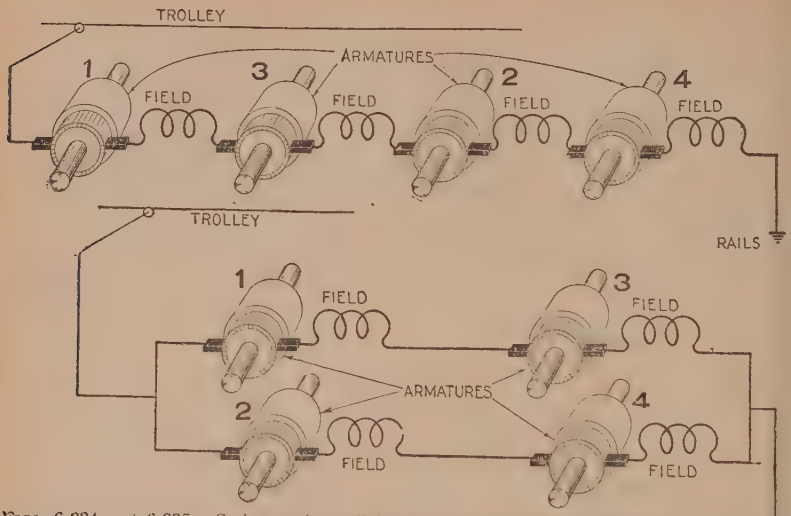
When two motors are in series each takes only half of the trolley voltage as explained in fig. 6,226.

In some few instances, further reduction in the resistance loss has been secured by using series, series parallel, or parallel connections as shown in figs. 6,227 to 6,229.

By this arrangement approximately one-half of the loss VSS[1], of fig. 6,226 is saved and the total resistance loss is approximately three-fourths



FIGS. 6,222 and 6,223.—Series and parallel hook ups for 600 volt four motor equipment.



FIGS. 6,224 and 6,225.—Series, and parallel hook ups for 600 volt four motor equipment.

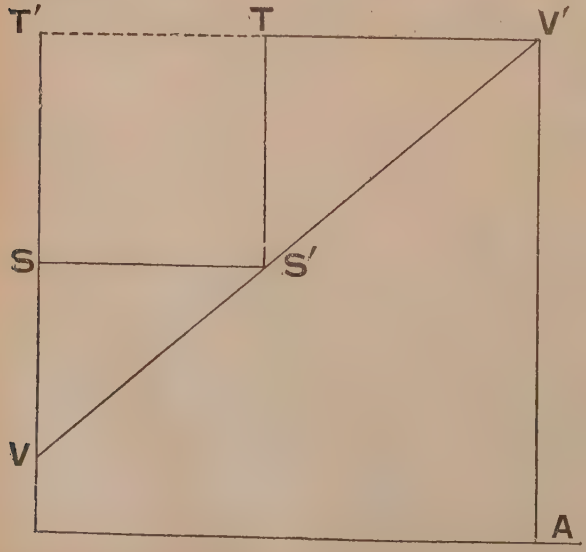
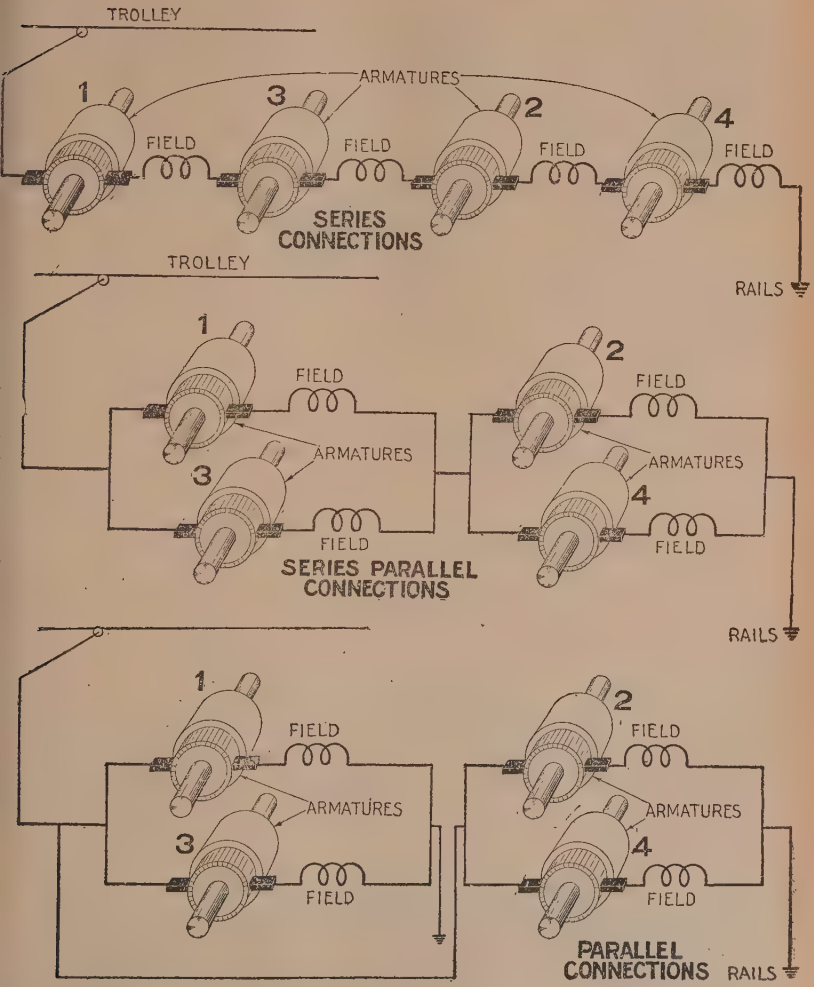


FIG. 6,226.—Diagram showing that the loss in resistors is approximately one-half the amount it would be without the series parallel connection. While in series the voltage for one motor and its resistor is only, SS^1, or half the trolley voltage, T^1TV^1. The energy delivered to the motor in either case is VS^1V^1A. With series parallel control, the resistance loss is $VSS^1 + TV^1S^1$, while with motors permanently in parallel, the loss is VT^1V, which is approximately twice as great.



FIGS. 6,227 to 6,229.—Series, series parallel and parallel hook ups for 600 volt four motor equipment.

of what it is with ordinary series parallel control, as shown in figs. 6,219, and 6,220 and figs. 6,222 to 6,226, or is approximately three-eighths of the amount it would be with the rheostatic control shown in figs. 6,218 and 6,221. However, it is an exceptional case where the reduction in resistance loss by using the connections of figs. 6,227 to 6,229 instead of those of figs. 6,222 and 6,223, justifies the additional complication in the control apparatus and wiring necessary to secure it. Therefore, series and parallel control as shown in figs. 6,222 to 6,225 is standard for car equipments.

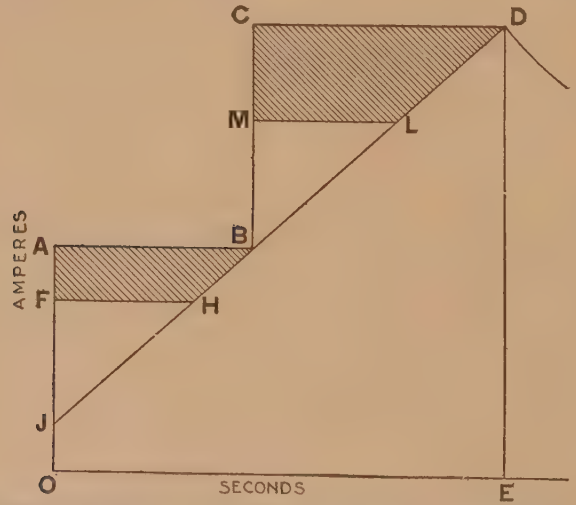


FIG. 6,230.—Field control diagram. In the diagram, AB and CD, indicate the currents per car taken from the trolley in series and parallel respectively, without field control. The area OABCDE, is a measure of the total energy taken from the trolley in starting, and the area, OJBDE, represents the actual input to the motors, while the areas, JAB, and BCD, show the rheostat losses. If field control be used, the currents are reduced to FH, and ML, with full field, but on the short field notches they are at B and D. The total energy from the trolley is represented by the area OFHBMLDE, while the energy delivered to the motors is the same as without field control, OJBDE, and the rheostatic losses are shown by the area, JFH, and BML.

Field Control Motors.—The use of field control motors increases the equipment efficiency in starting by reducing the resistance loss, as shown in fig. 6,230. From the explanation, it is evident that the rheostatic losses, and therefore the total energy taken by the car, are reduced by the amount indicated

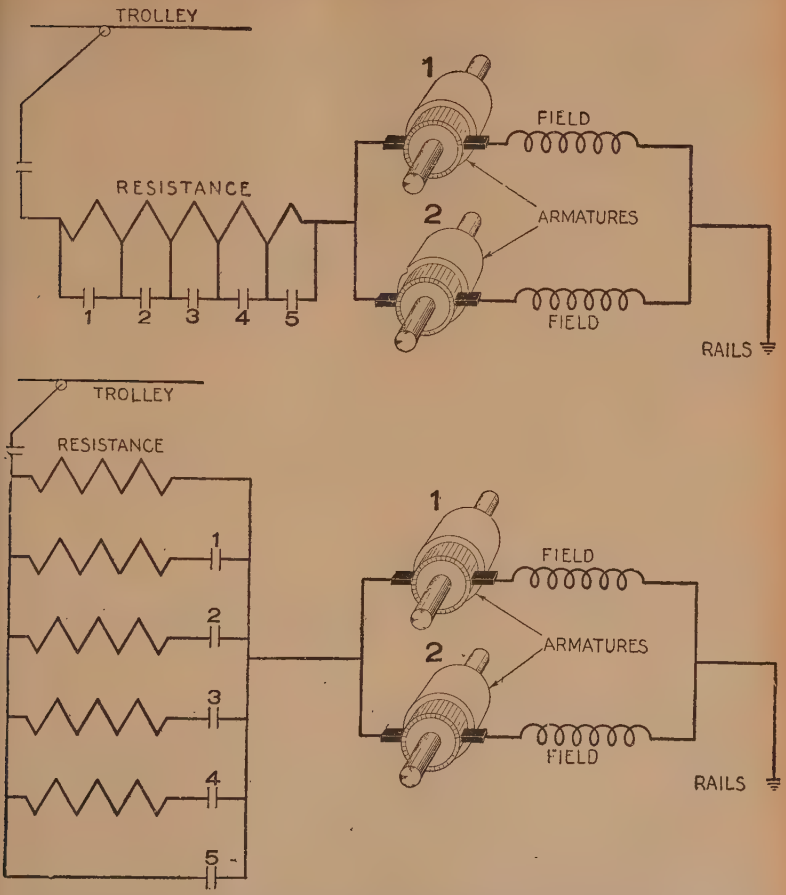


FIG. 6,231.—Diagram of two motor equipment showing series resistors used in starting. Switches for short circuiting the sections are indicated at 1, 2, 3, 4, and 5. When power is first applied all of these switches are open. They are closed consecutively in notching up the controller until all are closed. In this position the motors are running on full voltage without resistance in the circuit and this is an economical operating condition.

FIG. 6,232.—Diagram of two motor equipment showing parallel resistors used in starting. 1, 2, 3, 4, and 5 indicate switches which are all open at the start and are closed consecutively as the controller is operated. When switch 5 is closed the equipment is in an economical running connection.

by the areas FABH and MCDL. In various service tests, this reduction in energy consumption by the use of field control has been found to be from 5% to 17% of the total energy taken by the car.

Starting.—Three classes of resistor connections are used in starting.

With series resistors all of the resistance is in circuit at first and it is gradually short circuited by sections as shown in fig. 6,231.

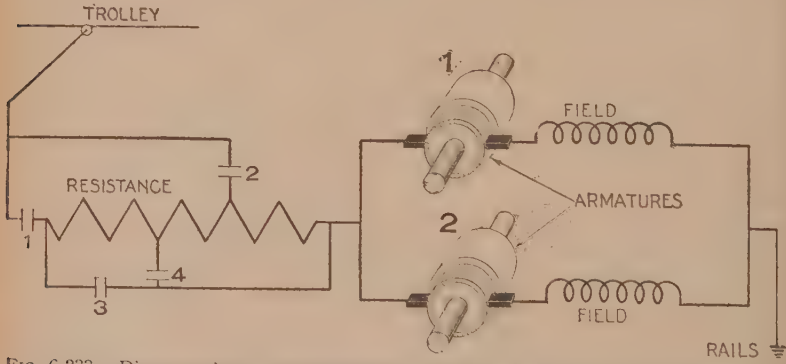


FIG. 6,233.—Diagram of two motor equipment showing series and parallel resistors. The sequence of operation of the switches in this case is indicated in fig. 6,234.

With "parallel resistors" only a part of the resistor is in circuit at starting and additional resistors are connected in parallel with the initial section by successive notches until finally the entire resistor is short circuited, as shown in fig. 6,232.

The third class of resistor includes those combinations using both series and parallel connections.

One such resistance is illustrated in fig. 6,233. The sequence of operation of the switches in this case is indicated by fig. 6,234, which shows by the circles which switches are closed on each controller point. Notch 5 is the running notch without resistance in circuit.

STEP	SWITCHES			
	1	2	3	4
1	●			
2		●		
3		●	●	
4		●		●
5	●	●	●	

FIG. 6,234.—Diagram showing sequence of operation of the switches in the hook up shown in fig. 6,233

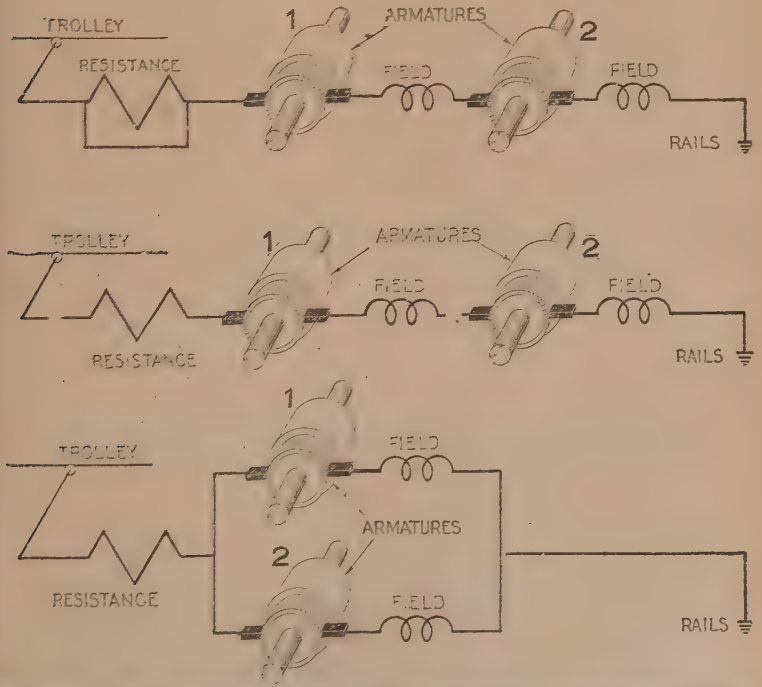
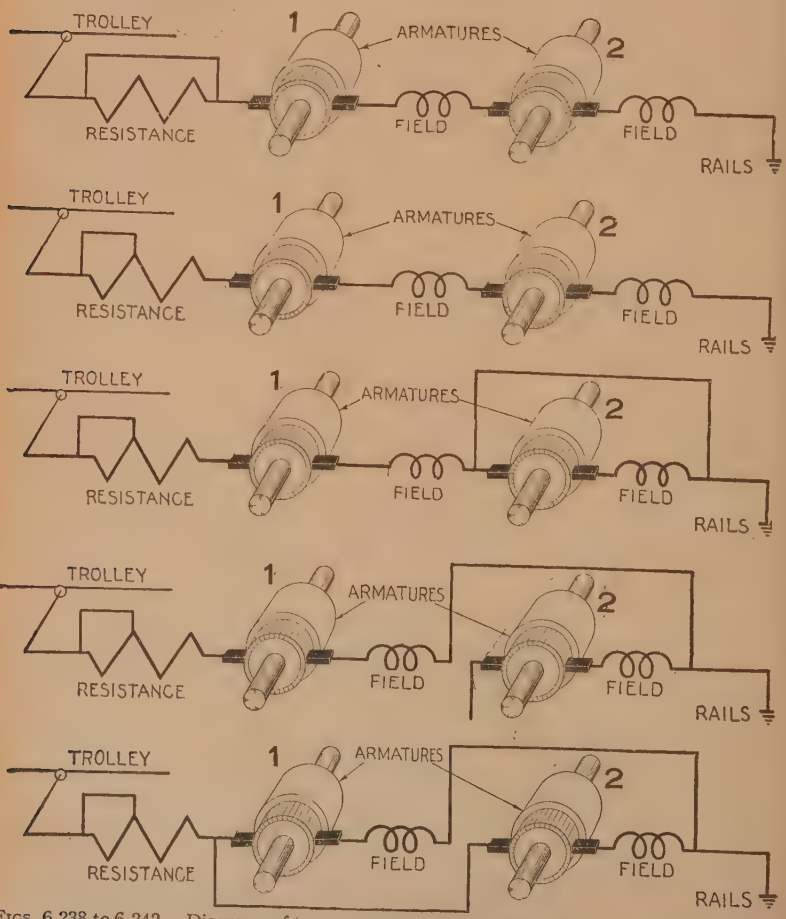


FIG. 6,235 to 6,237.—Diagrams of two motor equipment showing the connections for the last series, transition and first parallel points of the open circuit method.

Transition.—Three methods of making the transition from series to parallel connection of the motors are in use:

1. Open circuit;

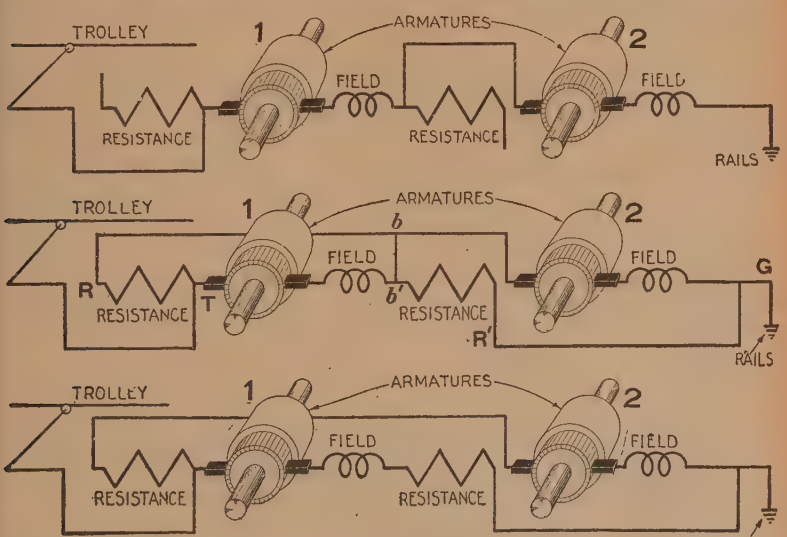


FIGS. 6,238 to 6,242.—Diagrams of two motor equipment illustrating the last series, transition and first parallel steps of the shunting method. Here there are three transition steps.

2. Shunting;
3. Bridging.

Open Circuit Method.—The connections for the last series transition and first parallel points of the open circuit method are shown in figs. 6,235 to 6,237. This is the method of series paralleling used with the L type of platform controllers most of which also use the method of parallel resistors.

These controllers were built only for large equipments, from 350 to 500 *h.p.* at 500 volts and since for equipments of such capacity it is now common



FIGS. 6,243 to 6,245.—Diagrams of two motor equipments showing bridging method. Two resistors are used. On the transition step the motors in series are receiving full trolley voltage through the circuit Tb^1bG and the two resistors are in series with each other between trolley and rails thus forming a circuit $TRbb^1R^1G$ in parallel with the motor circuit. A bridging connection bb^1, is made between the junction points of the two resistors and the junction point of the two motors and establishes two other parallel circuits, Tb^1R^1G and TRbG, each comprising one motor and one resistor in series. On the first parallel notch the bridge bb^1, is opened and the motors are in parallel with a resistor in series with each motor.

practice to use unit switch control, L type controllers may be considered as practically obsolete. Of course a number of L controllers which were installed in past years are still in successful operation.

Shunting Method.—The last series transition and first parallel steps of the shunting method of series paralleling the motors are shown in figs. 6,238 to 6,242. Here there are three transition steps:

1. First transition;
2. Second transition;
3. Third transition.

This method has an operating advantage as compared to the open circuit method in that only one-half of the torque is dropped during the transition instead of all torque being lost. Series paralleling by this method is used with most platform controllers of the K type, which also employ the method of series resistors, and with unit switch control except where automatic operation is required or the current handled is comparatively large.

Bridging Method.—This method is shown in figs. 6,243 tc 6,245 from which it is seen that the last series transition and first parallel steps of the bridging method of series paralleling the motors are indicated.

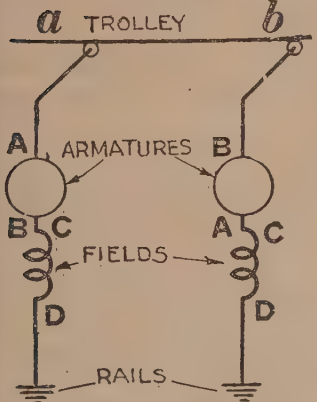
This method has an advantage over both of the other methods in that both motors are working all the time and none of the torque is dropped during the transition period. Bridging is used where automatic operation unit switch control is desired and with hand operated unit switch control, where heavy current is handled.

Reversing.—It is necessary to be able to run cars backward as well as forward. Since the driving motors are positively geared to the car axles, a change in the direction of motion of the car requires a change in the direction of rotation of the motor.

The direction of rotation of series motors *depends upon the relative directions of the current through the field and armature windings.*

If the direction of current through both field and armature be reversed, the direction of rotation will not be changed. A change in the relative directions of field and armature current, and therefore in direction of rotation, is made by reversing the connections of either the field or armature in the circuit.

Example.—In fig. 6,246, it *a*, represent the connections to run the car forward, *b*, shows the connections for backward operation.



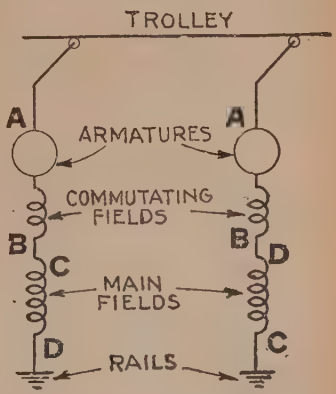


FIG. 6,246.—Diagram showing connections for forward and backward operation. At *a*, brush A, is connected to the trolley and brush B, to the positive side of the field. At b, the brush B, is connected to the trolley and A, to the positive side of the field. The negative side of the field is permanently connected to ground and the armature has been reversed. This is the standard method of reversing used with motors which do not have commutating poles.

FIG. 6,247.—Commutating pole motor hook up for reducing the voltage on the field coil insulation.

Commutating pole motors require that *the armature and commutating pole windings be connected so that the relative directions of current through them shall always be the same.*

It is further desirable that both the commutating and main field windings shall always be on the ground side of the armature on account of the reduced voltage strains on the field coil insulation. In order to secure these features, the commuting pole winding is permanently connected to the negative armature brush and the main field winding is reversed between the negative terminal of the commutating pole winding and the ground, as shown in fig. 6,247.

Electric Braking.—Track brakes are used to a limited extent with car equipments, in which case the controllers must be arranged to make the necessary connections. The energy for track brakes may be taken direct from the trolley or from the motors acting as dynamos driven by the stored energy in the car after the power is cut off.

For braking, *all the motors are in parallel and connected to the brake magnets through resistance which is varied as the car speed is reduced.*

In case of failure of the brakes, it is possible to brake the car by suitable manipulation of the controller and reverser, except where the equipment includes only a single motor or its equivalent of two motors permanently in series.

When a car is running without power there is a slight residual magnetism in the field poles although no current is flowing in the field coils and there is a tendency to generate voltage in the armature. With the reverser set for the direction in which the car is moving, this voltage is in such a direction that if it should produce a current through the field, this current would demagnetize the field which in turn would kill the voltage and current. Hence the motors will not pick up as series dynamos.

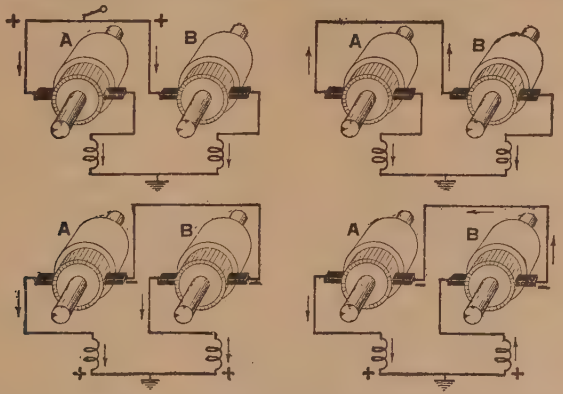
If, however, the car be moving forward and the reverser be thrown to its position for backward motion, the voltage set up in the armature by the residual magnetism tends to send a current through the field in such a direction that the field magnetism is increased which in turn builds up the armature voltage and current. In this way the motors are made to pick up as series dynamos.

An inherent characteristic of a series dynamo is that *it must be connected to a load in order to generate any voltage and the value of the voltage generated depends upon the amount of the load.*

If two motors be connected in parallel, with the reverser set for generation, both motors tend to generate in the same direction and therefore oppose each other.

In practically all cases one of the two motors is stronger than the other so that it "picks up" as a dynamo and the weaker motor runs from it as a motor tending to reverse the direction of motion of the car.

In fig. 6,248, is indicated by signs the voltage and by arrows the direction of current for two motors in parallel taking power from the trolley. In 6,249 the arrows show the tendency of armatures and fields to oppose each



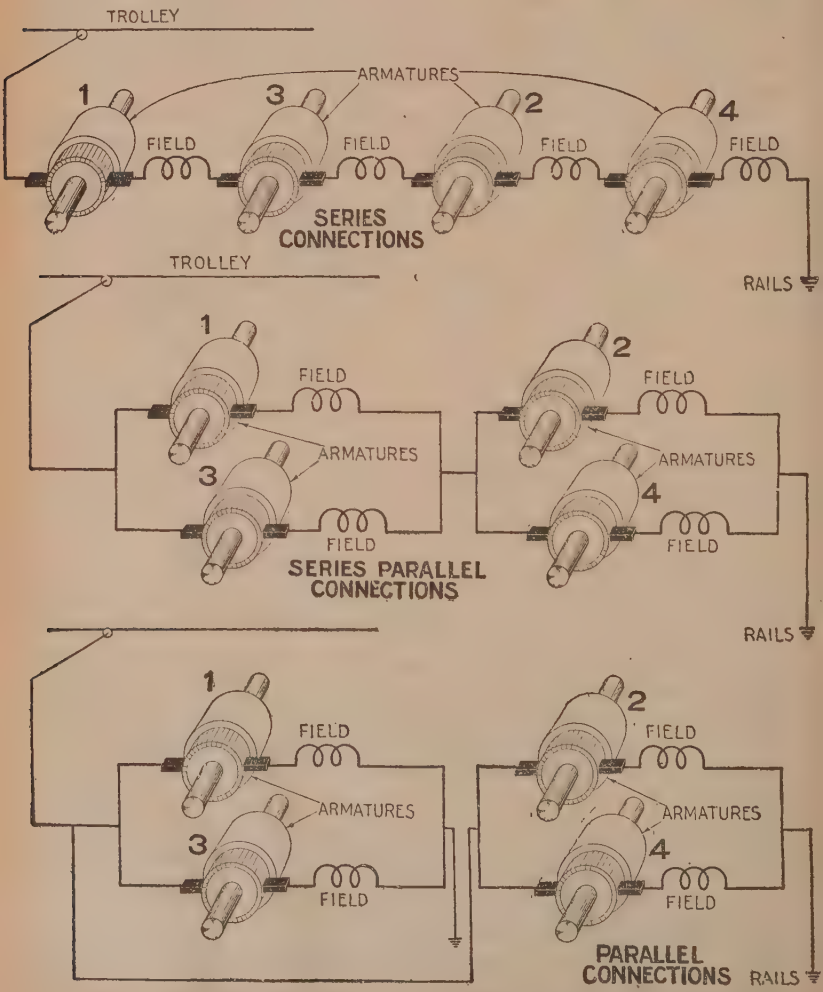
FIGS. 6,248 to 6,251.—Diagrams of two motors in parallel showing voltage and current conditions when taking current from the trolley, and when not taking current from the trolley.

other and maintain an electrical balance with no current flowing, which is the condition when the car is running without power. When the reverser is thrown to the backward position while the car is moving forward, the connections are as shown in fig. 6,250, and the signs and arrows respectively indicate the voltage and the direction in which current tends to flow initially.

If it were practicable to manufacture motors absolutely identical electrically and magnetically, a condition of balance would exist with two such motors connected as in fig. 6,250 and no current would flow.

Practically, however, one of the motors will always generate a higher voltage than the other and sufficient to drive current

through it in the direction opposite to the voltage which it tends to generate.



FIGS. 6,252 to 6,254.—Diagrams of four motor equipment arranged for three speed control.

In fig. 6,251 motor A, is operating as a dynamo driven by the momentum of the car, and is generating a higher voltage than motor B, thus furnishing power to operate B, as a motor tending to retard the car. This scheme is used only for emergency braking. When two motors are permanently in parallel, as with a 600 volt quadruple equipment, this emergency braking is secured by simply moving the controller to the off position and then throwing the reverser. With 600 volt double, 1,200 volt quadruple equipments, or 600 volt quadruple equipments arranged for three speed control, as in fig. 6,252, where all motors are in series at first, in order to secure emergency braking it is necessary to move the controller to the off position, throw the reverser, trip the circuit breaker, so that line power cannot be applied, and then move the controller up to the first notch on which motors are in parallel. This method of braking is equivalent to running one motor of a pair as a dynamo and the other as a load. It is also possible to use other apparatus for furnishing the load.

The two motors of a pair *may be operated as dynamos in either series or parallel and an external resistance connected in series with them for absorbing the energy which they generate.*

This is known as electric braking.

The external resistance may be replaced by the magnet coils of the track brakes which act on the track and wheels, and hence give effective braking with much less current through the motors than with electric braking through resistance.

With either electric braking or track brakes, it is necessary to reverse the motors to make them "pick up" as dynamos.

If the motors be in parallel when used for this purpose, it is also necessary to interchange the fields; that is, in fig. 6,252, connect the field of motor A, in series with the armature of motor B, and field B, in series with armature A, in order to secure equal voltages from the two motors and stability of the system. If this interchange of fields were not made, emergency braking would occur just as though no resistance or brake magnets were connected across the motor terminals.

Protection.—To furnish protection against too heavy overloads or grounds and short circuits which may occur in an

equipment, an adjustable circuit breaker, as shown in fig. 6,257 is connected in the cable between the trolley and the controller.

Circuit breakers are rated according to the current which they will carry continuously and for any specific equipment, are selected so that the current rating of the breaker is approximately two-thirds of the nominal one hour current rating of one motor multiplied by the number of motors in parallel in the equipment.

The breaker is usually set to trip at a current 50% greater

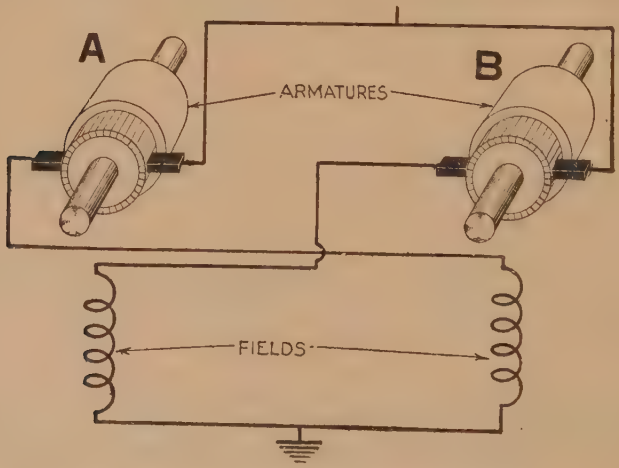


FIG. 6,255.—Two motor hook up to cause them to "pick up" as dynamos.

than the nominal current rating of one motor multiplied by the number of motors in parallel per equipment.

Example—A 600 volt car equipped with four motors, each rating 100 amperes for one hour, should have a circuit breaker with a continuous rating of $\frac{2}{3} \times 100 \times 4 = 267$ amperes. Ordinarily this breaker should be set to trip at $1.50 \times 100 \times 4 = 600$ amperes. On locomotives it is customary to set the breaker to trip at double full load on the motors. In the above case this would be $2 \times 100 \times 4 = 800$ amperes.

For protection against lightning and surges which occur in the contact line (trolley or third rail) *a lightning arrester is connected next to the collector and a choke coil is connected in the power circuit between the lightning arrester tap and the circuit breaker.*

If lightning or a line surge tend to produce an abnormal voltage at the car, which in turn tends to send a heavy rush of current through the equipment, the choke coil limits the current rush and piles up the voltage next to

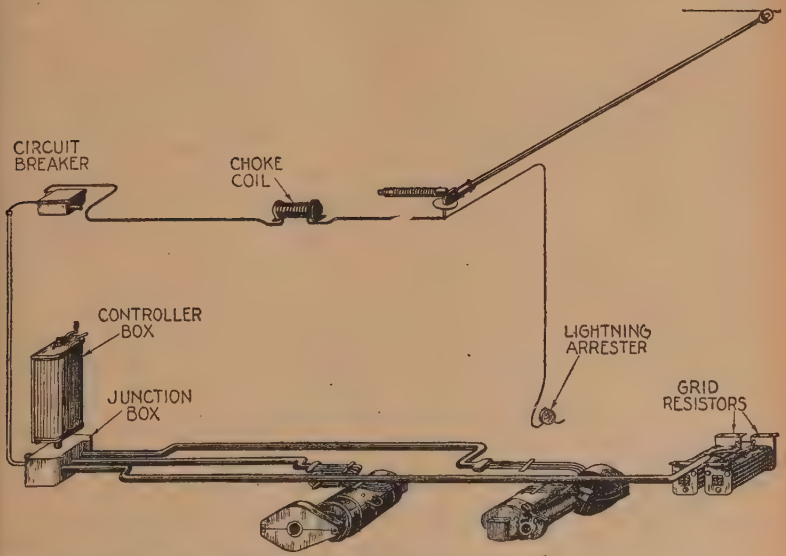


FIG. 6,256.—Westinghouse single end type K control equipment.

the arrester until the current finally jumps to ground through the arrester, the tension is relieved and normal conditions are re-established.

Fig. 6,256 shows in skeleton form the apparatus and connections for a single end car equipment employing two 600 volt commutating pole motors, platform type controller and auxiliary apparatus as described.

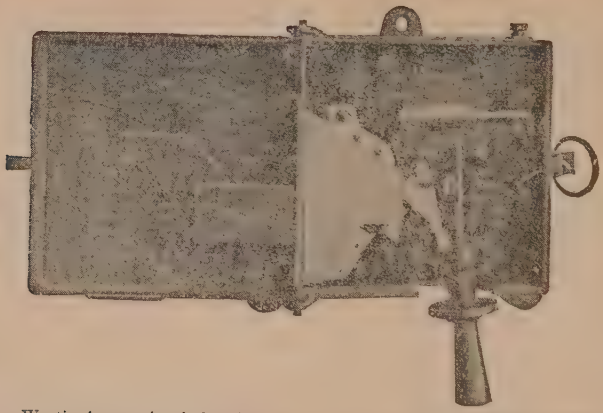


FIG. 6,257.—Westinghouse circuit breaker to furnish protection against too heavy overloads or grounds and short circuits which may occur in an equipment.

TEST QUESTIONS

1. *What are the functions of a control apparatus on a car?*

2. *What would result if full trolley voltage were applied to the motors of a car at standstill?*

3. *Name an important part of the control apparatus.*

4. *How are the various control connections made?*

5. *Does a controller increase the voltage by steps or uniformly?*

6. *Is an even or an odd number of motors used?*

7. *Describe the method of control with one and two motor equipment.*

8. *Describe the method of field control.*

9. *Name three classes of resistor connections used in starting.*

10. *Name three methods of making a transition from series to parallel connection of the motors.*

11. *Describe the open circuit method.*

12. *What connection is used in the shunting method?*

13. *Describe the bridging method.*

14. *Upon what does the direction of rotation of a series motor depend?*

15. *In reversing, what are the requirements of commutating pole motors?*

16. *What is understood by the term "electric braking"?*

17. *Describe the method of operating motors in electric braking.*

18. *What is necessary in electric braking to cause the motors to pick up as dynamos?*

19. *Describe the protective equipment.*

CHAPTER 136

Control Equipment

The type of apparatus described in this chapter is applied to cars and locomotives for 600 volt, 1,200 volt and 1,500 volt installation. The instructions and data covering this class of equipment apply in general to electro-pneumatic control equipment of special construction, such as would be required to multiple with other manufacturers' apparatus. Therefore, the information here given relating to individual pieces and parts of apparatus, such as controller boxes, switch groups, line switches, reversers, air cylinders, relays, etc., is practically the same regardless of special requirements.

For the benefit of platform operators, a general list of the apparatus involved is here given. The list of apparatus covers an equipment for four 65 *h.p.* 600 volt motors arranged for double end operation in trains on 600 volt trolley.

Main Circuit Apparatus	*Control Apparatus*
2 Trolleys.	2 Master controllers.
1 Lightning arrester.	
1 Main knife switch.	2 Control and reset switches.
1 Main fuse box.	
1 Control box.	1 Control resistor.
1 Reverser (included in control box)	2 Train line junction boxes.
1 Main grid resistor.	2 Train line receptacles.
1 Set insulating details.	
1 Set pneumatic details.	1 Train line jumper

Trolleys collect the current from the overhead trolley wire usually by means of a revolving contact wheel.

Lightning arrester protects the control apparatus and main motors from lightning and other abnormal voltage surges

Main knife switch, fig. 6,258, disconnects the main motor circuit from the trolley circuit so that the controlling apparatus may be operated independently of the main motors for inspection purposes.

FIG. 6,258.—Westinghouse main switch. This is a knife switch for disconnecting the apparatus from the trolley circuit.

Main fuse box, fig. 6,259, provides ultimate protection to the equipment against sustained currents above the ratings of the apparatus, but below the setting of the overload trip protection.

NOTE.—The control equipment described and illustrated in the accompanying text is the Westinghouse type HL unit switch control equipment.

Control box and switch group, figs. 6,260 and 6,261. The main part of the equipment contains the resistance switches, the transition switches and where no separate circuit breaking line switch unit is used, the line switches. The difference between a control box and switch group is that the former includes the reverser mounted on one of the end plates, while a separate reverser is used with the latter.

FIG. 6,259.—Westinghouse main fuse box to protect apparatus against excessive current.

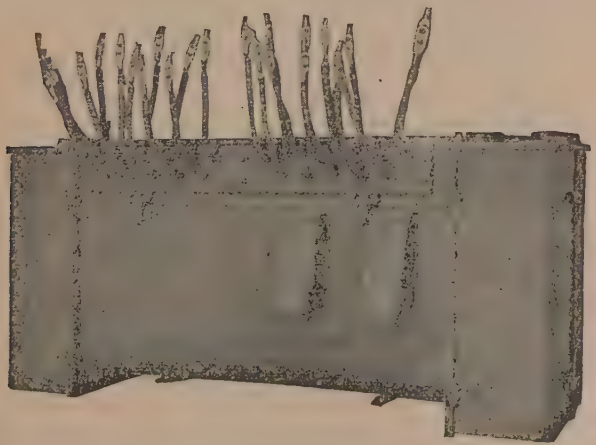


FIG. 6,260.—Westinghouse control box complete with covers.

Reverser, fig. 6,262, as its name implies, reverses the direction of current in the motor fields or armatures by interchanging the connections. This reversal of current in the field or armatures with relation to the armature or field current reverses the direction of running.

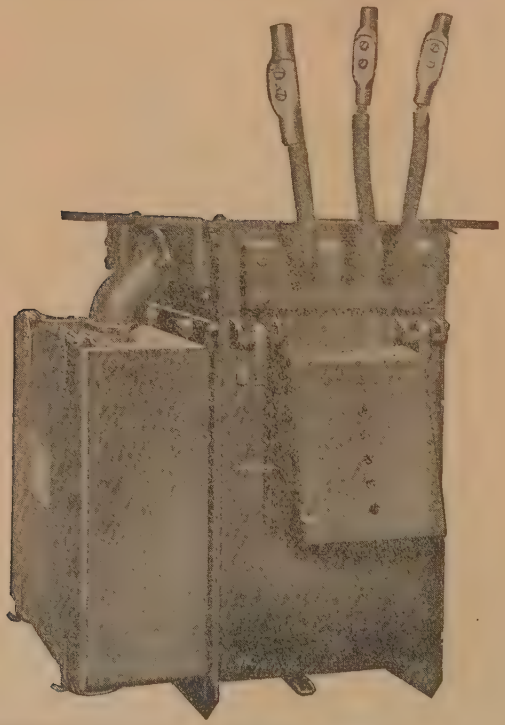


FIG 6,261.—Westinghouse line switch complete with covers.

Main grid resistor, fig. 6,263, limits the amount of current which flows and thus controls the torque developed by the motors. Notching of the master controller, which operates the switches in the control box or switch group, cuts out the resistance step by step, thereby permitting the motors to gradually speed up and hence the car to accelerate without excessive current and without undue discomfort to passengers.

Master controller, fig. 6,264, controls the starting and accelerating of

the car. Closing and opening of main motor circuits are accomplished indirectly by the master controller energizing or de-energizing the control circuits of the switches in the control box or switch group.

Control and reset switch, figs. 6,265 and 6,266, energizes or cuts off power from the control circuit. It also resets the overload trip by energizing the reset coil.

Control resistor, fig. 6,267, provides relatively low voltages for the control circuits to the operating coils of the switches.

Train line junction boxes, fig. 6,268, are used to simplify the installation of control wiring and the inspection of equipments as a whole.

FIG. 6,262.—Westinghouse reverser for separate mounting.

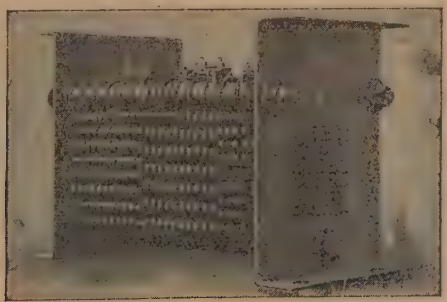


FIG. 6,263.—Westinghouse standard grid resistor for control circuits of motors. With all the resistance in, the amount of current the motors get is small and the car starts slowly; as the resistance is cut out, it gains speed.

FIG. 6,264.—Westinghouse master controller shown without cover. *It consists of* a cylinder with contact rings, operated by the control handle, which open and close the circuits of the motor control switches, energizing and de-energizing their operating coils which cause air valves to admit air under pressure, into cylinders that control the moving parts of the switches.

FIGS. 6,265 and 6,266.—Westinghouse control and reset switch shown with and without cover.

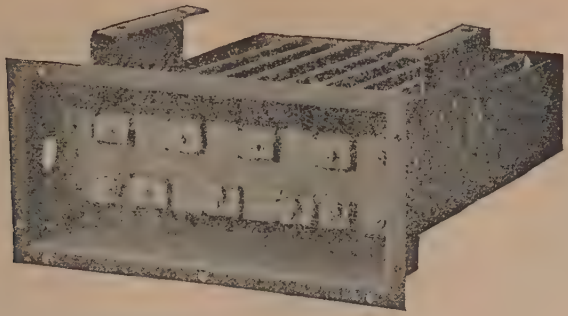


FIG. 6,267.—Westinghouse control resistor.

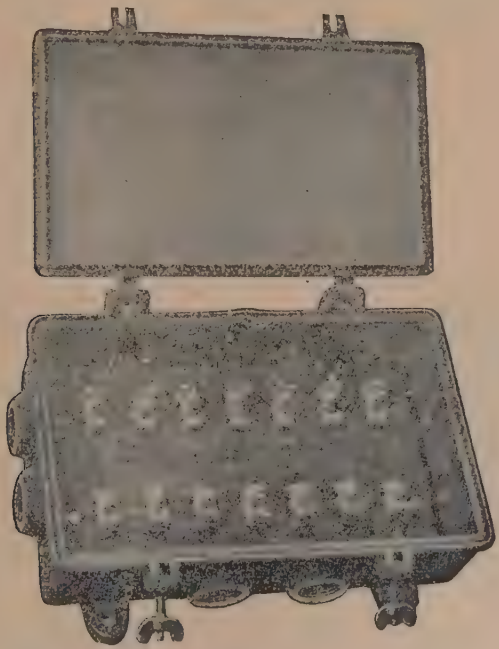
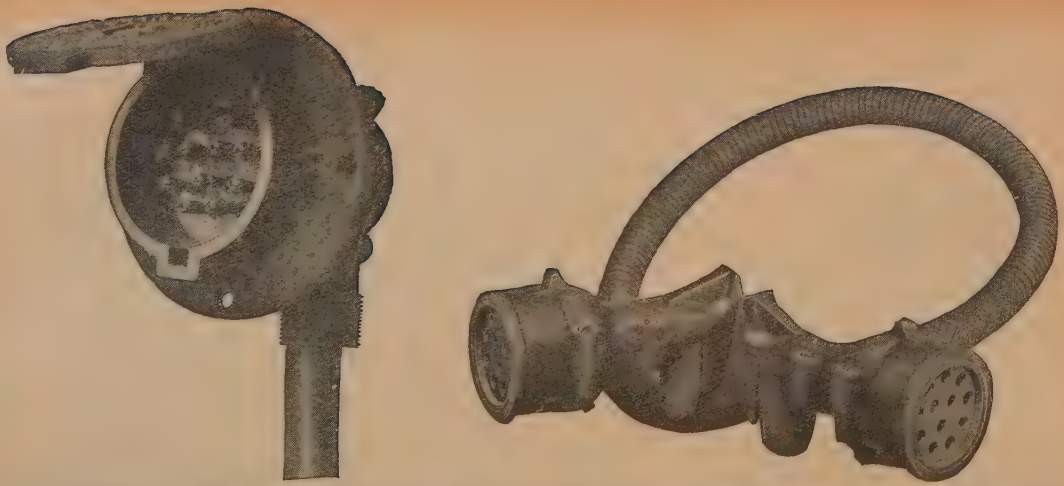


FIG. 6,268.—Westinghouse train line junction box open.



FIGS. 6,269 and 6,270.—Westinghouse train line receptacle and jumper for connecting the control wires of one car with those of another thereby enabling the motors of several cars to be controlled from one controller.

Train line receptacles, figs. 6,269 and 6,270, form control circuit terminals or extensions at the ends of car which in conjunction with the train line jumper completes the control circuits between adjacent cars of a train.

Insulating details are used to insulate the frame supports of the apparatus from ground to reduce voltage strains between parts of different voltages.

Pneumatic details provide means for cutting off the compressed air supply, for equalizing air pressures, and for cleansing the air. In some cases where air pressures above 75 lbs. are used a reducing valve for cutting down the pressure is supplied.

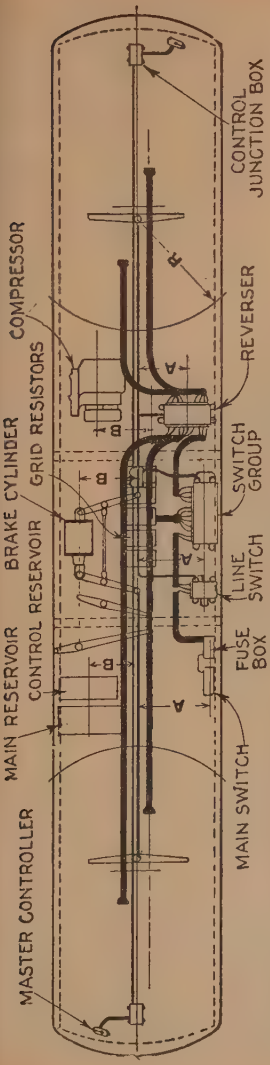


FIG. 6,271.—Typical car layout equipped with Westinghouse type HL unit switch control.

Operation

Single Car Operation. — *When taking charge of a car*, see that the main fuse is in place, the main switch and the pump switch are closed and the control air cut out cock is open. Be certain that all air tanks are drained of any moisture or sediment which may have collected in them.

If the trolley has been lowered or the pump switch opened, do not attempt to move the car until the main reservoir pressure has reached at least 60 lbs. pressure and the pump governor has cut out; then try the air brakes to see that they are operative before applying power to the car.

Place the controller handle in the "off" position and move the handle of control switch to the "reset" position momentarily to see that it shows a flash, thus indicating that the control fuse is intact and that power for operating the control and reset circuits is available. Then place the handle of the control switch in the "on" position.

Place reverse handle in forward or reverse position as desired, then move controller handle notch by notch in the usual manner. The last series and last parallel notches are the two running notches and give "half" and "full speed" respectively.

The main and reverse handles are so interlocked that the former cannot be moved unless the latter be in either the forward or the reverse position, and the latter cannot be moved unless the former be in the "off" position.

Merely moving the reverse handle does not throw the reverser. After putting the reverse handle in the desired position, the main handle must be put on the first notch in order to throw the reverser.

Should the reverser refuse to throw from the master controller for any reason, it can be moved by opening the cover and touching the pin on top of one or the other of the two magnet valves. In case the reverser fail to

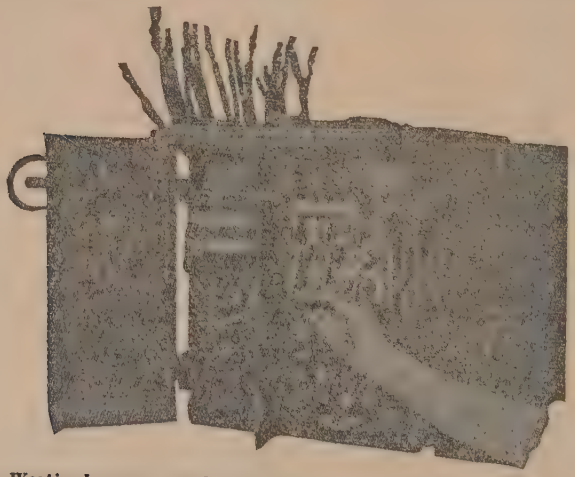


FIG. 6,272.—***Westinghouse control operation 1.*** Cutting out motors.

throw pneumatically it can be thrown by means of the hand lever, or, in case of the reversers mounted on the control box end plate, by inserting short piece of pipe over the lug provided for this purpose.

If the switches open, due to the operation of the overload trip return the controller handle to the "off" position and "reset" by momentarily closing the reset circuit by means of the control and reset switch. If, when the master controller is notched up, the overload trip again blow, the cause should be investigated. It is probable that either the master controller is being advanced too rapidly or there is a ground or "short" in the main circuits. If the difficulty be in one of the motors, the motor may be disconnected from the circuit by means of the motor cut out switch shown in fig. 6,272. If the car be otherwise disabled, the main circuit cut out

switch should be opened. The car may then be operated in train as a trail car or withdrawn from service.

Motor cut out switches are either of the main circuit or control circuit type, and are usually mounted in one end of the switch group or control box, as in fig. 6,272. When a control circuit cut out switch is used, it is provided with a shaft having a squared end extension made to fit the master controller reverse handle.

Motors are numbered 1, 2, 3 and 4, starting from one end of the car. Since it is difficult to determine which is No. 1 motor, for example, and which is No. 4, particularly on a double end car, the cut out switches are arranged to cut out motors in pairs, No. 1 and No. 4 (the two outside motors) or No. 2 and No. 3 (the two inside motors).

FIG. 6,273.—*Westinghouse control operation 2.* Adjusting reducing valve to change air pressure.

In case of damage to a motor, it is only necessary to determine whether it be an inside or an outside motor and open the corresponding switch.

With one pair of motors cut out of the circuit on four motor equipments, using main circuit motor cut out switches, manipulation of the master controller gives series parallel control of the remaining two motors.

Series parallel operation cannot be obtained with two motor equipments nor with four motor equipments using the control circuit type of cut out switch when one or a pair of motors is cut out. Normal operation of the master controller simply produces straight rheostatic acceleration.

If the unit switches fail to operate at any time, see that the fuse in the control and reset switch is in place. If it has blown, replace it. Before touching this fuse the trolley pole should be lowered, as this fuse is connected directly to the cable leading to the trolley. See that the control and reset switch makes contact, and that it shows a flash when opened with the controller on the first notch. Try the "reset;" if it do not show a flash when opened, try resetting by tripping the latch of the overload trip relay located on the end of the switch group or the line switch by hand.

If none of these tests show the cause of the trouble, remove master controller cover and observe whether the various fingers make contact on the drum segments, and whether a flash occurs when controller is moved from the first notch to the "off" position.

In case the controller show no flashing when moved from the "first" position to the "off" position, the trouble exists in the circuit from the trolley through the control resistor. The cover of the control resistor should be removed and connections examined. Trouble with control resistors is a rare experience.

Finally, with the trolley down and the main and control switches open, inspect the control box, switch group and line switch (if used) and the

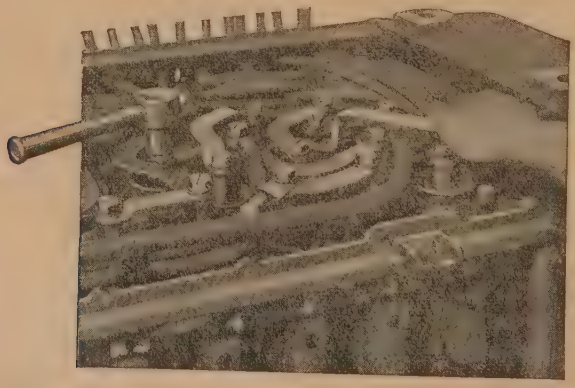


FIG. 6,274.—*Westinghouse control operation 3.* Tightening terminal bolts.

reverser and see that the interlock fingers are making contact with the plates against which they rest and that none of the small wires leading to them or to the magnet valves is broken or disconnected.

If, after making the above investigations, the trouble cannot be located the car should be reported as dead and removed to the car barn where a more thorough inspection can be made.

Emergency Braking.—*In case of extreme emergency only*, when the brakes have failed, a four motor equipment may be stopped

by moving the reverse handle to the opposite running position and putting the main handle on the first notch. *After braking by this means has been set up the reverse handle must not be moved until the car has come to a dead stop.*

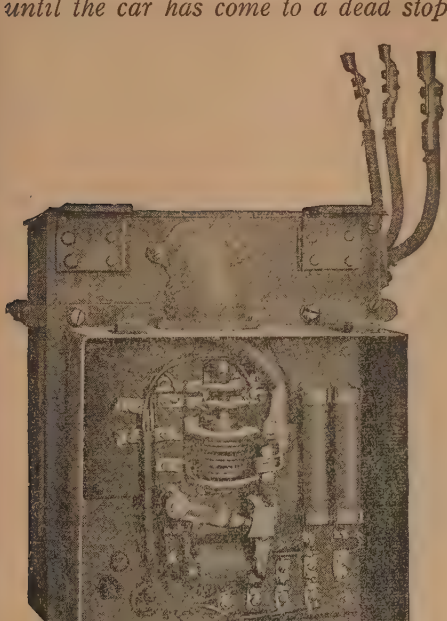


Fig. 6,275.—End view of Westinghouse line switch.

The braking effect produced is very severe, cannot be regulated, and should only be used when every other means of stopping the car has failed. This method of retarding the motion of the car is known as dynamic braking.

A two-motor equipment may be stopped under the same circumstances, by throwing the reverse handle to the opposite running position and then moving the main handle to any parallel notch.

The reverse handle must not be moved again until the car has come to a dead stop. Should the reverse handle be moved after the dynamic braking has once been set up, the heavy regenerated current will be broken at the reverser fingers and contacts, resulting in excessive burning of these parts.

Train Operation.—*Where two or more cars are to be operated as a train,* see that they are mechanically coupled and the air brake connections made. Then insert control train line jumpers in corresponding receptacles on each car.

The lid of the train line receptacles has a lug arranged to engage with a similar lug on the jumper head to hold it in place. Be sure these lugs properly engage each other when jumper heads are inserted.

Bus line receptacles and jumpers are similar in general construction to train line receptacles and jumpers, and should be handled in the same manner. Care should be taken *not to insert or withdraw them unless the trolleys on all cars are down or all bus line disconnecting switches are open. Only one pair of master controller handles* should be in place on the train, and these should, of course, be on the master controller at the head of the train.

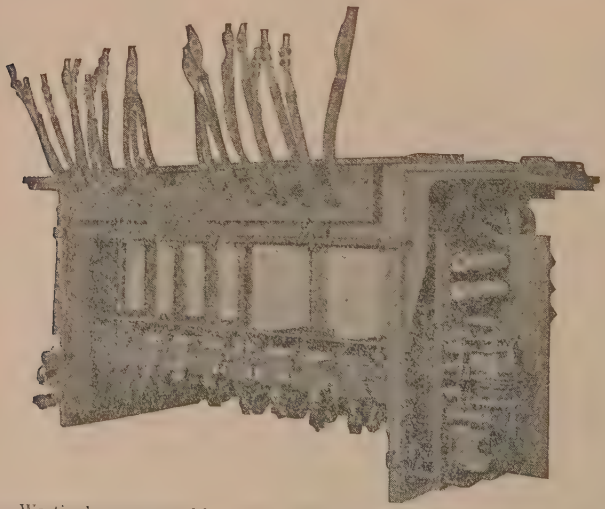


FIG. 6,276.—Westinghouse control box with covers removed showing overload trip relay and front side of switch group.

All control switches except the one at the operating master controller should be in the "off" position.

After the above precautions have been observed a train of two or more cars is then handled exactly as if it were a single car.

The operation of 1,200 *volt and* 1,500 *volt equipments is essentially the same as that of the* 600 *volt equipments*. They differ only in details of construction and in the arrangement of circuits.

Locomotives.—The type control here presented is used not only for the control of motor equipments on electric railway cars, but is extensively used where the heavy duty incident to electric locomotive service makes a reliable type of control necessary. The chief difference between car and locomotive equipments lies principally in method of mounting; for cars the main parts are mounted underneath the car body, while for

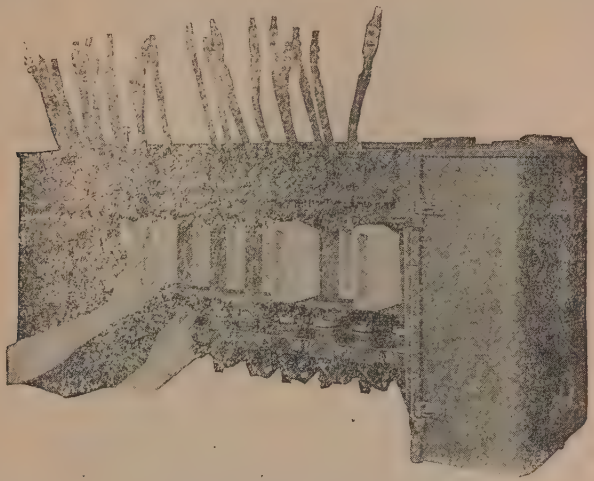


FIG. 6,277.—*Westinghouse control operation 4.* Removing arc boxes.

locomotives they are usually mounted on structural iron framing inside of the locomotive cab. The instructions herein apply equally to both locomotive equipments and car equipments.

Maintenance

General.—*Satisfactory operation* cannot be obtained from railway equipments of any sort, and failures on the road prevented, unless a careful and systematic inspection of the apparatus is

made at regular intervals. *The work of maintaining* equipments is usually divided into three classes: light inspection, heavy inspection and overhauling.

The frequency of inspections necessary is usually set on a basis of car mileage and the work to be done, and depends very largely on local conditions. The following suggestions are based on average conditions, and will

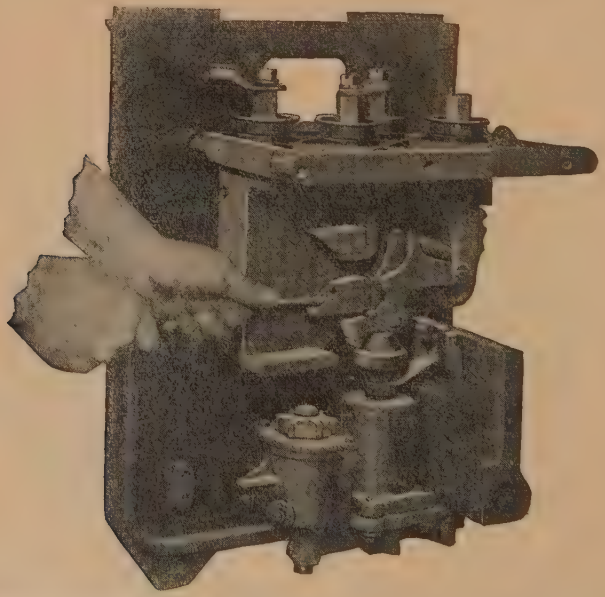


FIG. 6,278.—*Westinghouse contro. operation 5.* Removing contact tips.

serve as a general guide until the particular modifications necessitated by local conditions, if there be any, can be determined. For example, it may be found that the work classed as heavy inspection can be taken care of partly during the light inspection and partly when overhauling.

Light Inspection.—Before any attempt is made to inspect the control box, switch group, line switch or reverser, the main

switch should be opened to insure that the car cannot be accidently moved with anyone under it. Furthermore, the opening of the main switch will allow the operation of the control for inspection purposes.

The mileage which may be allowed between light inspections will depend on local conditions, and must be determined by trial. As a rule, city equipments should be inspected every 500 to 1,000 miles, while interurban equipments may be run from 1,000 to 2,000 miles between inspection periods which is the equivalent to about once a week for the two classes of equipment.

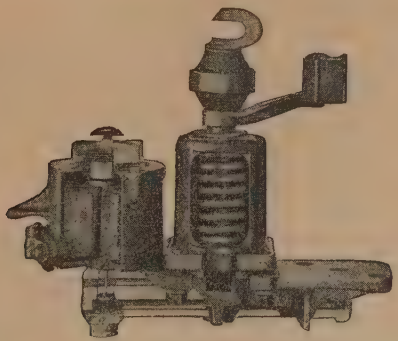


FIG. 6,279.—Westinghouse cylinder and magnet valve unit cut to show interior details.

The covers of each piece of apparatus, including control box or switch group, line switch, fuse box, reverser, changeover switch, master controllers and control switches, should be opened, the condition of the apparatus noted, and any necessary cleaning or light repairs made.

The arc horns, arc chutes, contact tips and switch shunts should be given particular attention and any horns that are burned off, chutes that are charred, burned through or nearly so, or shunts that show any indication of breaking, should be replaced. In case the arc chute of an important circuit breaking switch be in bad condition, and no spare arc boxes be at hand, they may be interchanged with those from a switch which merely cuts resistance in or out and is not subject to arcing duty. Should the contact tips become burned and rough they may be smoothed off with a file. Care should be taken to prevent arcing horns striking lower arcing blocks, as this causes the breaking of these horns.

The piston rod guides on every light inspection should each be given *one or two drops of oil*, by means of a can with a long spout. Care should be taken not to get any more oil than absolutely necessary in the cylinder, as oil is very injurious to the piston leathers. The cylinders should be lubricated only at heavy inspection periods.

Any air leaks from valves or cylinders should be corrected and any necessary small repairs made.

The interlocks on the switch group, line switch and reverser should be examined and cleaned if necessary.

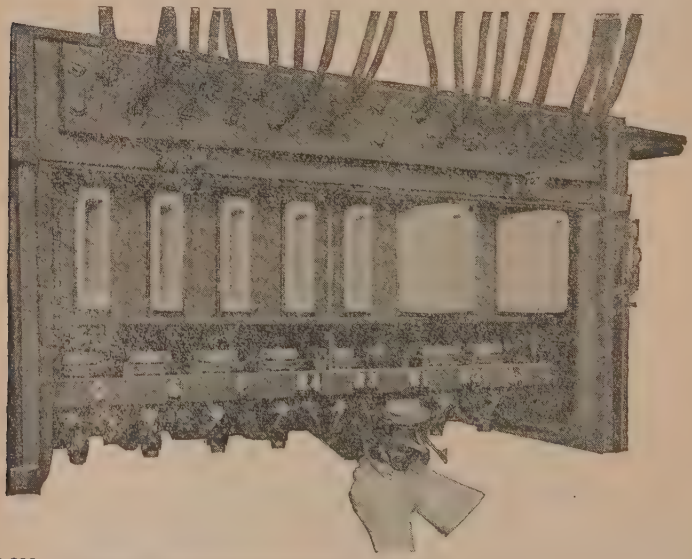


FIG. 6,280.—*Westinghouse control operation 6.* Taking out a cylinder and magnet valve.

The movement of each switch and that of the reverser should be noted by pressing the pins on the top of the magnet valves to be sure they work freely.

The switch group should be cleaned by blowing out the dirt with an air hose. This may be attached to the equalizing reservoir if no other source of air be available, but the moisture should first be drained from the tank before attaching hose. Blow from the interlock side.

Dirt, smoke or copper dust deposit on the piston insulators, valve magnets, or on the insulating surfaces of the control box should be removed with a

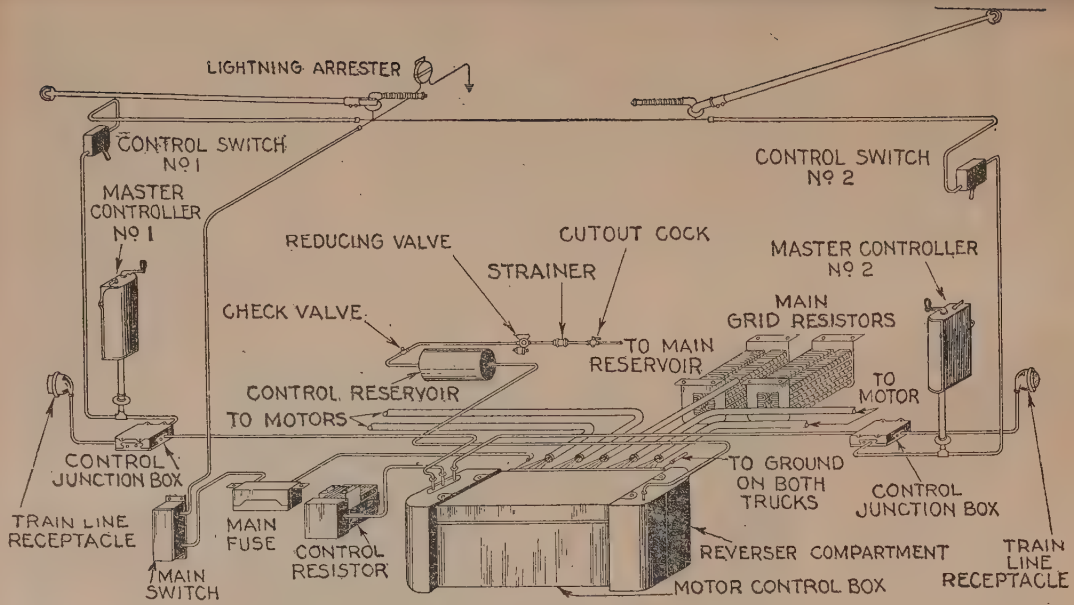


FIG. 6,281.—Isometric view of Westinghouse unit switch control equipment.

piece of cheese cloth. In using a cloth or waste for cleaning the controller parts, be careful so that the cloth or ravelings do not catch in the interlock fingers and pull them back far enough to give the spring a permanent set. Some types of fingers are provided with stops, which would prevent this injury, but there are other types where the movement is not definitely limited by a stop and which might be injured by the careless use of a cloth or waste.

The grid resistors should be examined to see that none of the grids is broken, and that the cables are tight in the terminals.

All air tanks should be thoroughly drained to get rid of any water and sediment that may be in them.

The switches and reverser should be operated through a complete cycle and the sequence checked after all the foregoing inspections and adjustments have been made.

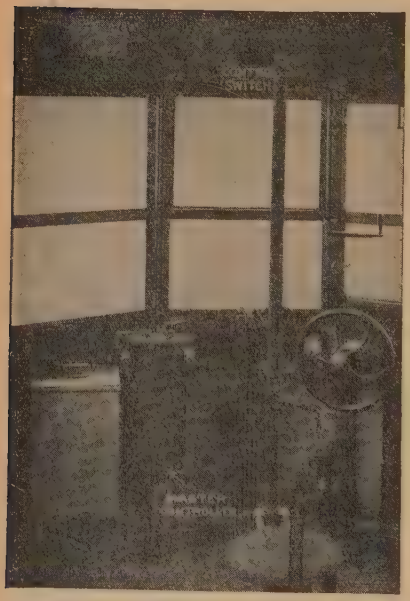


FIG. 6,282.—Interior of operator's cab showing Westinghouse master controller and control switch. The master control is for electro-pneumatic control of motors in modern heavy traction cars.

Heavy Inspection. — A heavy inspection in general should be made about every three to six months where cars are regularly in service.

All apparatus should be thoroughly cleaned and lubricated and all necessary repairs made, in addition to work ordinarily done at light inspections. *The air strainer* should be taken down and the curled hair which it contains washed in gasoline after the first three months' operation, and about every 12 months thereafter.

The reducing valve setting should be checked by screwing an inspector's gauge in the drain cock of the equalizing reservoir, to be sure that 70 lbs. pressure is secured on the control apparatus. At least every six months it should be taken apart, wiped thoroughly with a cloth free from lint, removing all oil from the piston. In reassembling, a good grade of dry graphite should be used sparingly on the slide valve *but no oil should be used on the piston.*

After setting or cleaning the reducing valve, the control should be operated up to full multiple about 10 or 12 times and the action of the gauge on the equalizing reservoir noted during operation. If the pressure drop more than three pounds during this process, the valve has not been properly assembled or cleaned and should be again taken apart and readjusted.

The insulating bolts and washers and the insulating pipe and conduit couplings on the control box or switch group, line switch, reverser and grid

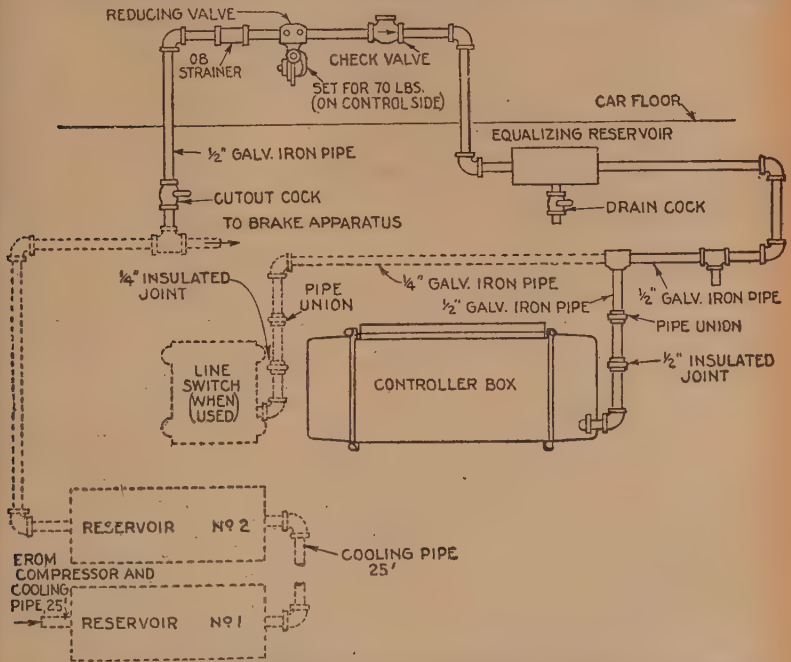
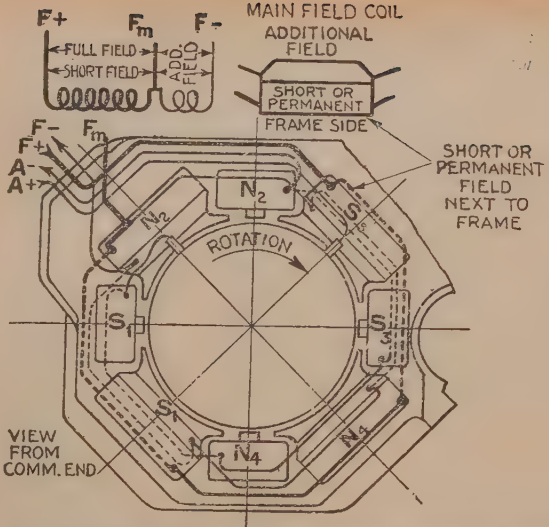


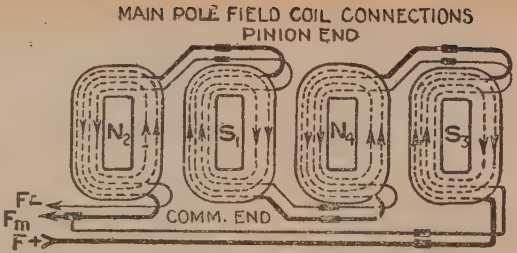
FIG. 6,283.—Westinghouse piping diagram of 600 volt installation showing pneumatic details.

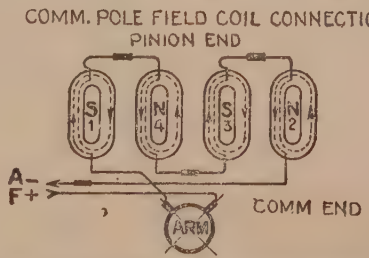
resistors should be thoroughly cleaned, and if the surface be not smooth and shining a coat or two of thin shellac should be applied.

The nuts holding the grid resistor frames together should be inspected and tightened to take up any shrinkage which may have occurred.

The top covers of switch group and line switch should be removed and the copper bolts holding the switches and blowout coils tightened, if necessary,







FIGS. 6,284 to 6,288.—Westinghouse connection diagrams for field controlled motors. Motor leads are marked as here shown, which indicates by heavy and light lines the relative capacity of the winding sections. For four motor equipments (with motors connected in pairs) the resistance of the car leads connecting the F-leads of two motors of a pair to their common terminal in the control box should be the same. This is also true for the car leads connecting the Fm leads to their common terminal in the control box. ***Wiring precautions*** with *tapped field motors*.—When wiring cars equipped with tapped field motors it is necessary to take into consideration the resistance or balance of the motor circuit cables. The precaution just mentioned is not necessary for two motor, 600 volt equipments or 1,200 and 1,500 volt, two or four motor equipments. Frequently after all wiring connections have been made it is found that the motors are connected so as to oppose or buck each other, preventing the car starting under power. This indicates that the connections are not made to conform with the wiring diagram. Care should be taken to see that tapped field motors are connected in accordance with the official diagram because of the limited capacity of the added field section. In re-arranging connections between the motors and the car circuits, interchange of cable lead grouping should all be made on the leads from the car wiring. This will maintain all motors leads from the motors in the same position and therefore permit of a universal interchange of motors of the same type on any car. Dotted lines show connections at pinion ends.

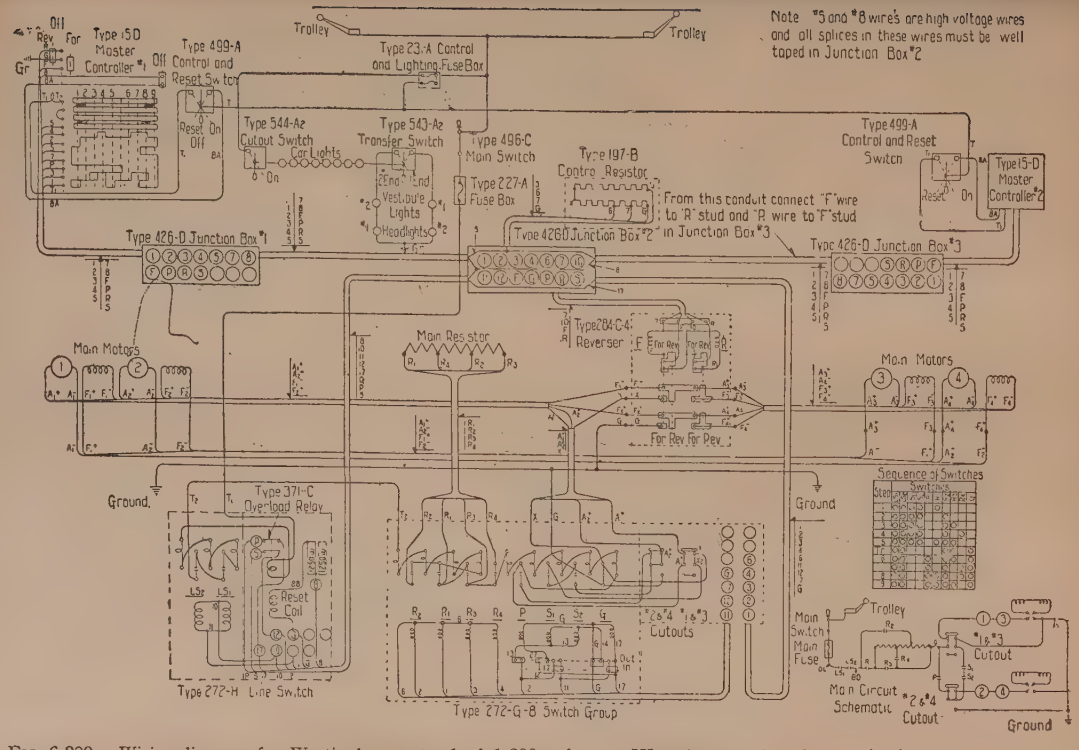
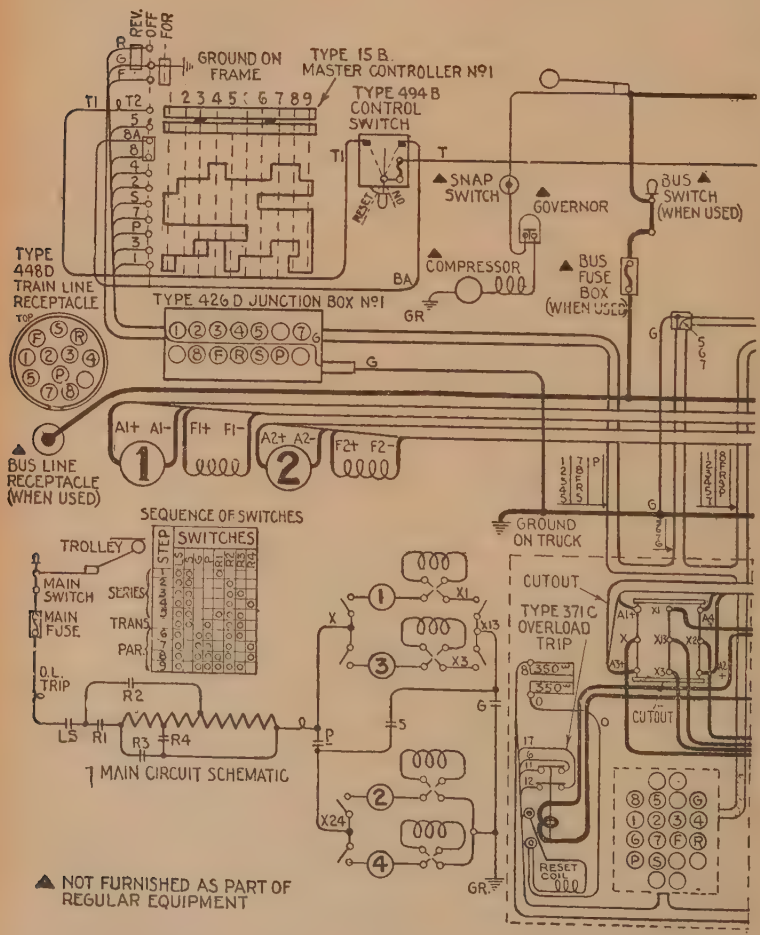
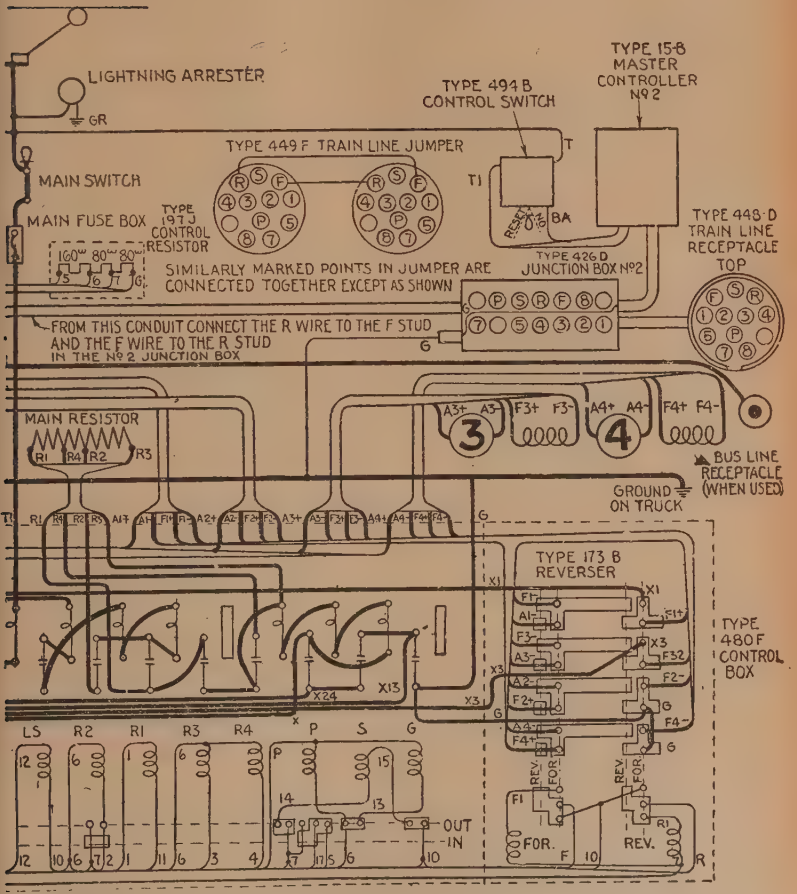


FIG. 6,289.—Wiring diagram for Westinghouse standard 1,200 volt type HL unit control equipment for four 50 *h.p.* 600 volt motors, connected two in series.



FIGS. 6,290 to 6.293.—Wiring diagram for Westinghouse standard 600 volt type HL unit



FIGS. 6,290 to 6,293.—*Text continued.*

control equipment for four 65 *h.p.* 600 volt motors.

by means of the special "goose neck" wrench as shown in fig. 6,274, supplied for this purpose with the equipment. The top bolts holding the strap connectors should first be loosened with the special socket wrench, also supplied as a part of the equipment. Caution must be taken not to stretch the bolts. Any dirt should be blown out of the top compartment with an air hose.

Any insulating surfaces which cannot be given a reasonably clean polished surface by wiping with cheese cloth should be given a coat or two of clean *thin* shellac. This should be thoroughly dry before the car is used. The various pivot pins of the switch arms, the contact fingers and the piston hooks should be lubricated with a drop or two of oil. The bolts holding the shunts should be tightened.

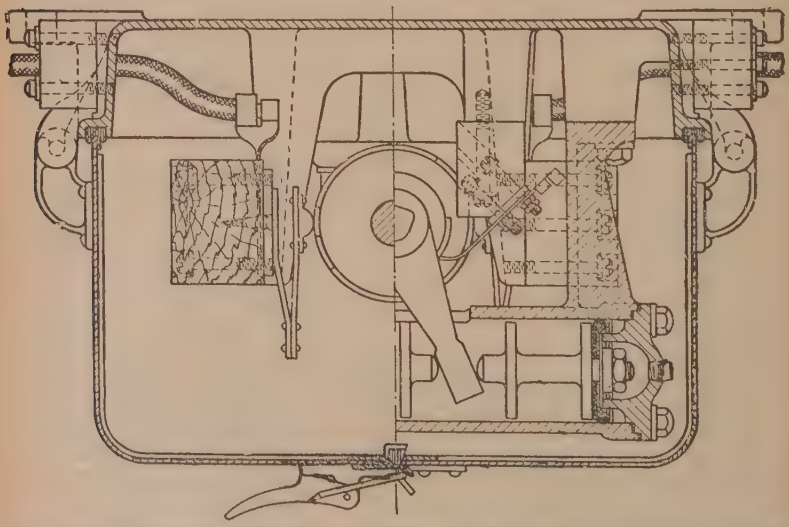


FIG. 6,294.—Westinghouse reverser. ***Adjustments:*** The portion of the finger which makes contact with the drum should be true so that when pressed against a flat surface it makes contact throughout its entire width. Adjustment of each finger may then be easily made by using a wrench where necessary to bend the finger spring to insure proper alignment. After adjustment spread grease on the drum segment and move the drum back and forth to thoroughly lubricate contact surfaces several times. Each main finger should be adjusted so that it drops from 1/16" to 1/8" below the surface of the drum segment when it is in the open or "off" position. If the finger drop too far there is danger that the drum segment will jam the finger. If the finger be not adjusted far enough below the surface of the drum segment there will not be sufficient pressure between the contacts to carry the current and overheating and welding of contacts may result.

If a switch become sluggish in its action at any time and cannot be brought to normal operating speed by oiling the piston rod guide, or by lubricating the piston with oil through the vent in the top of the cylinder, the cylinder should be taken apart and cleaned. It should be noted that the use of ordinary lubricating oil for lubricating the cylinder and piston leathers is entirely contrary to recommended practice. The oil specified by the manufacturers should be used.

The upper and lower valve stems of switches and reverser should be taken out and, if gummy, should be washed in gasoline and a little gasoline should be poured through the magnet core in order to wash the seats. When taking out the valves for this purpose, *each must be returned to its original position*, as each stem is ground in to fit its own seat.

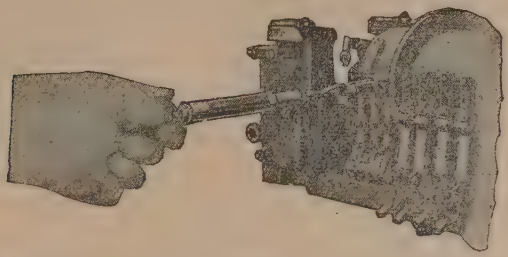


FIG. 6,295.—***Westinghouse control operation 7.*** Checking control finger pressure.

The interlock contacts should be lubricated by wiping with a piece of cheese cloth, moistened with a thin lubricating oil. The finger tension should be tested and adjusted if necessary, as shown in fig. 6,295.

The covers of the control box or switch group and reverser should be examined to see that they fit tightly and that the felt which makes them dust tight, as well as the insulation on them is in place and in good condition.

The entire interior of the control box or switch group, line switch, reverser and changeover switch should be wiped clean, special attention being paid to the piston rod insulators. The covers should then be tightly closed.

Any dirt on the outside of control box, switch group, line switch, changeover switch or reverser, which has a tendency to fall inside when the covers are opened, should be cleaned off, and preferably, the entire outside should be cleaned.

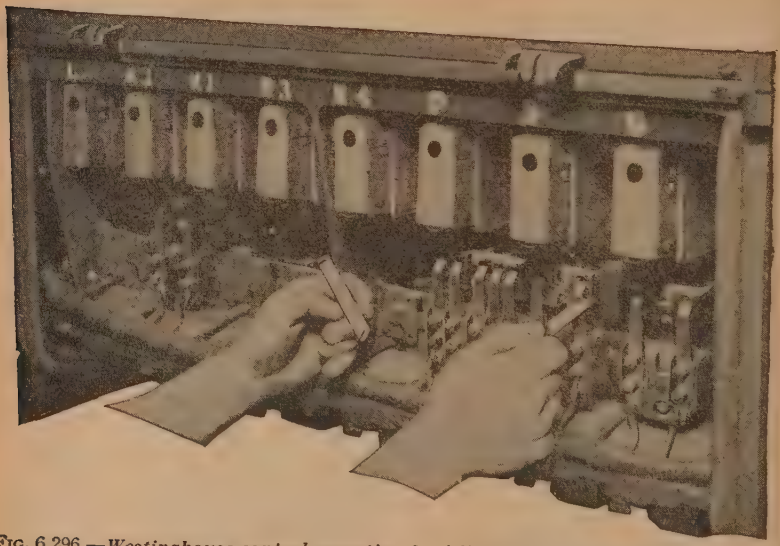


FIG. 6,296.—*Westinghouse control operation 8.* Adjusting interlock fingers.

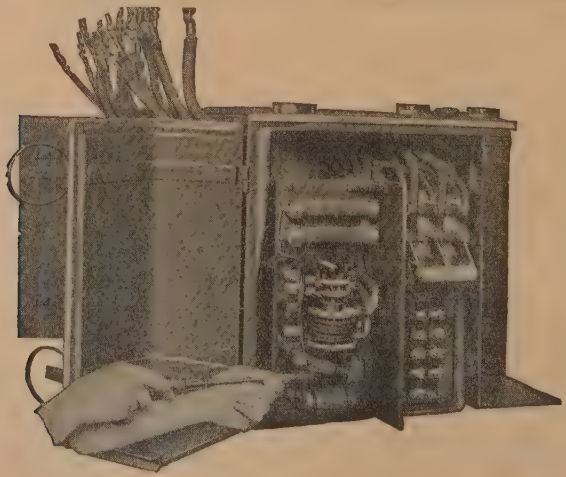


FIG 6,297.—*Westinghouse control operation 9.* Adjusting type 371 overload relay.

The frames of the control box or switch group, line switch, reverser, and grid resistors *should be tested for ground* by means of a bank of lamps connected to the trolley. If found to be grounded, the cause should be located and corrected.

The screws through the insulating base on which the reverser fingers are mounted should be tightened, if necessary, to take up any shrinkage that may have occurred during service.

All junction boxes and terminal boards should be examined for dirt or loose connections.

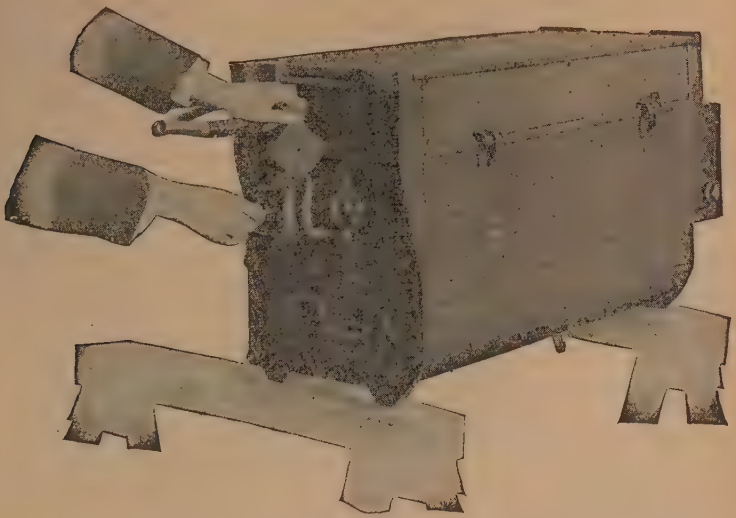


FIG. 6,298.—***Westinghouse control operation 10.*** Adjusting type 392 overload trip.

The master controller fingers should be examined for wear, and if necessary, adjusted to have a lift of $\frac{1}{16}$ inch, and to make good contact and then lubricated by wiping with a greasy cloth. Finger tension should be adjusted if necessary, as shown in fig. 6,295.

The master controller drum and reverser drum should be examined to see if there be any cutting of the contact surface by the fingers. If cutting be found, the drum and fingers should be smoothed up with fine emery cloth.

The parts of the interlocking and star wheel mechanisms of the master controller should be examined to see that they work freely and are in good order. They should be oiled when necessary. The handles should fit their respective positions properly.

Train line receptacles should be examined to see that the hinge joints and springs are in good condition, so that the covers automatically close when the jumper is removed and thus protect the contacts from the weather. The split contacts should be examined and if compressed should be adjusted to their original condition.

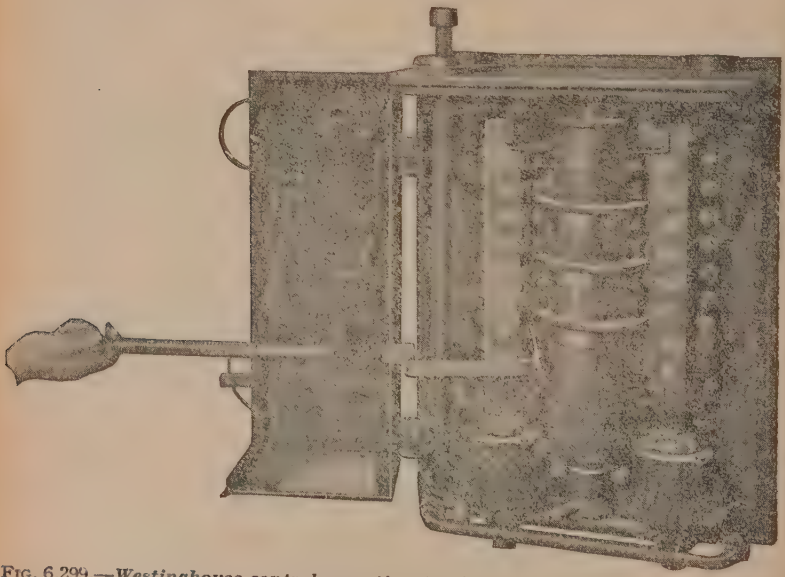


FIG. 6,299.—***Westinghouse control operation 11.*** Reverser mounted on control box end plate.

TEST QUESTOINS

1. *Give a list of the apparatus used in general with electro-pneumatic control.*

2. *Describe the method of electric braking in case of extreme emergency.*

3. *What should be done before two or more cars are to be operated as a train?*

4. *Does the operation of* 1,200 and 1,500 *volt equipments differ from the* 600 *volt equipment?*

5. *What is the chief difference between car and locomotive equipments?*

6. *What is necessary for satisfactory train operation?*

7. *In how many classes is the work of equipments usually divided?*

8. *On what is the frequency of inspection based?*

9. *Describe the light inspection.*

10. *Upon what does the mileage between light inspections depend?*

11. *How is each piece of apparatus inspected?*

12. *Describe what attention should be given to the following: piston rod guides, air leaks, interlocks, switch groups, grid resistors.*

13. *How often is the heavy inspection made?*

14. *Describe the various operations of making a heavy inspection.*

CHAPTER 137

Air Brakes

In this type of brake which operates by the expansive property of compressed air, the air is compressed by a suitable pump located upon the engine and is stored until needed for use. When it is necessary to apply the brake, a portion of the stored air is allowed to pass into the brake cylinder. This cylinder is fitted with a piston which the escaping air moves outward. It is so connected with the brakes that its movement is communicated to the shoes and applies them.

To meet the needs of the various conditions of service, there are several types of air brake known as:

1. Straight air brake.
2. Emergency straight air brake.
3. Automatic air brake.
4. Automatic variable release air brake.
5. Quick acting automatic air brake.
6. Combined automatic and straight air brake.
7. Electro-pneumatic air brake.

Ques. For what service is the straight air brake adapted?

Ans. For moderate speed city surface line cars which are operated as single units.

Ques. How does the emergency air brake differ from the straight air brake?

Ans. It provides means to overcome the objectionable length of time required to apply the brakes, so that they may be applied quickly in case of emergency.

Ques. What is the meaning of the word "automatic" as applied to air brakes?

Ans. It denotes that in case of accident such as the parting of a train, bursting of an air pipe, etc., the brake is automatically applied.

Ques. For what service is the automatic variable release type air brake used?

Ans. For high speed interurban cars which are operated the greater part of the time in trains.

Ques. What is the feature of the automatic variable release type air brake?

Ans. This type of equipment provides a braking effect during retardation that can be maintained practically constant. The brakes may be quickly applied and released as frequently as desired, and can be partially released after an application has been made.

Ques. What is the adaptation of the quick acting automatic air brake?

Ans. For long trains to reduce the time required to apply the brakes.

Ques. How does the quick acting type differ from the variable release type?

Ans. It differs in that the triple valve is so designed as to feed both auxiliary reservoir and train line pressure into the brake cylinder.

This procedure not only causes each car to aid in quickly reducing the train line pressure throughout the train, but it decreases the drop in train line pressure which must be produced at the head car.

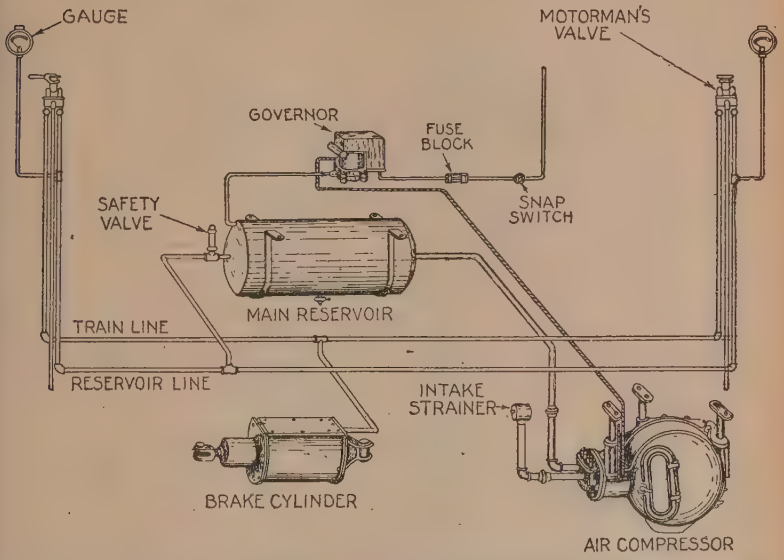


Fig. 6,300.—General Electric straight air brake equipment, showing the essential parts and pipe connections.

Ques. What is the object of the electro-pneumatic type of air brake?

Ans. It is designed for long trains.

Straight Air Brake.—In this type of air brake *the brake cylinder is connected directly to the motorman's valve which governs*

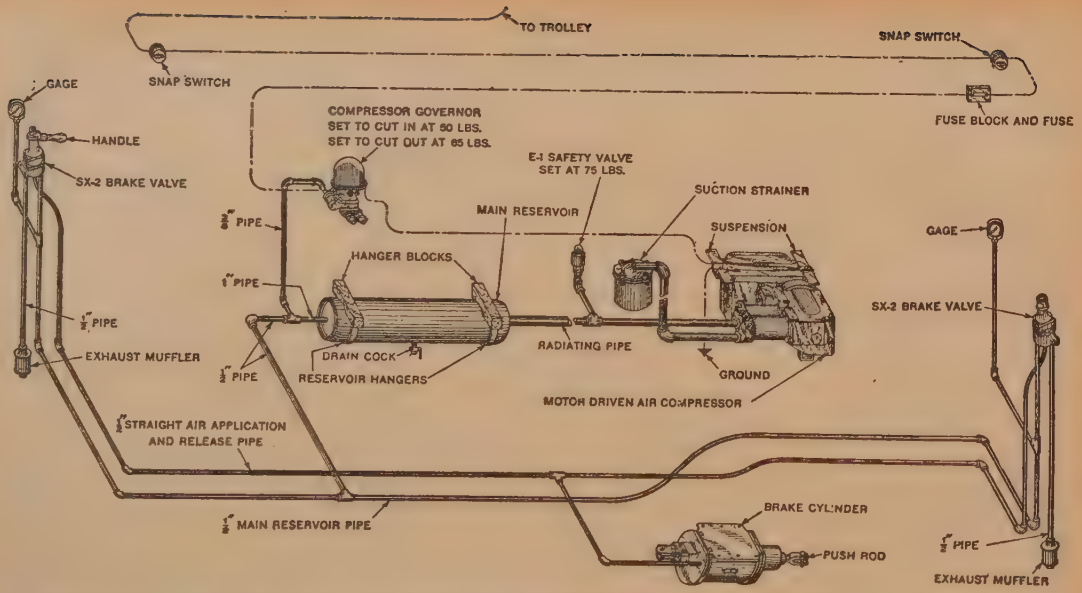


FIG. 6,301.—Westinghouse straight air brake equipment; pictorial view showing parts and pipe connections.

the admission of air to the brake cylinder and the exhaust of this air from the cylinder to atmosphere.

The brakes are applied by admitting air to the brake cylinder and are released when the air in the cylinder is exhausted to atmosphere. The general arrangement of this system is shown in fig. 6,301.

This type of equipment is composed of the minimum number of parts which can be installed and maintained at small cost and provides a means for controlling the speed of a car with a degree of flexibility.

A straight air brake equipment for a double end motor car consists of—

1. Compressor and auxiliaries:

a. Motor driven air compressor;

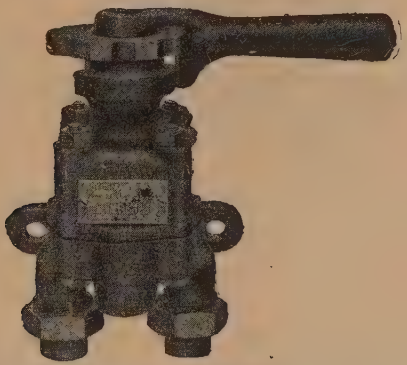


FIG. 6,302.—Motorman's valve for General Electric straight air brake system. This is a three way valve of the rotary type. The principal parts are the valve body, bonnet, valve stem and rotary valve. The rotary valve operates on a raised seat formed on the upper surface of the valve body. The ports of the rotary valve and valve body are machined accurately to size and position, and are located so as to perfectly balance the valve and reduce wear to a minimum. The stem is steel, case hardened, and is provided at the base with a ball seat which prevents leakage between the stem and bonnet. The bonnet is provided with a bushing of composition material which serves as a bearing for the stem and can be renewed when worn. The surface of the valve quadrant which is machined to indicate the operating positions, is case hardened to reduce wear. The bonnet is provided with a case hardened wearing pad which relieves the stem of strains due to the operator leaning on the handle.

b. Intake strainer;

c. Suspension set.

2. Pressure regulating equipment:

a. Air compressor governor;

b. Insulating connection;
c. ½ in. safety valve.

3. Cab equipment:

a. Motorman's valve;
b. Motorman's valve handle;
c. Single hand pressure gauges;
d. Snap switch;
e. Cutout with fuse.

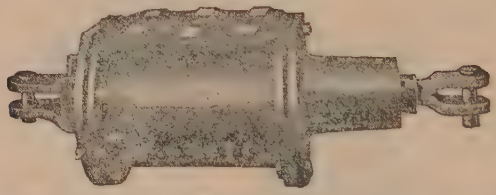


FIG. 6,303.—Brake cylinder for General Electric straight air brake system. ***In construction,*** the cylinder is fitted with a tubular piston rod which surrounds the push rod which attaches to the live cylinder lever. This construction permits of the brakes being applied by hand without moving the brake cylinder piston.

4. Brake details:

a. Straight air brake cylinder complete with push rod.

5. Main reservoir and accessories:

a. Main reservoir;
b. Reservoir hangers;
c. Drain cock.

The control of the brakes is by means of the motorman's valve, shown in figs. 6,300 and 6,302. This is a three way valve and the functions performed are:

1. Release position: Direct connection is made between the train line and exhaust through a large port.

2. Slow release and running position: Train line is connected to exhaust through a restricted port.

3. Lap position: All ports are blanked. This is the only position in which the handle can be removed.

4. Service application position: Connection is made between the main reservoir and train line through a series of small ports.

5. Emergency position: In this position the valve handle is at the extreme right and connection is made from the main reservoir to train line through a large port.

Rules for Operating a Straight Air Brake.—Before starting the air compressor see that the reservoir drain cocks are closed. Next, start the air compressor by turning the switch to the on position. When the gauge hand shows maximum main reservoir pressure, and before starting the car, make a service application of the brakes by moving the motorman's valve handle to the service application position to see that the brakes apply, which will be indicated by the brake cylinder piston moving out and forcing the shoes against the wheels. If the brakes apply properly with a service application, move the valve handle to the release position to see that they release properly, which will be indicated by the brake cylinder piston moving back in the cylinder and allowing the shoes to hang free of the wheels.

Running: Have the motorman's valve handle in the release position while running.

Service stops: In making ordinary service stops, place the motorman's valve handle in the service application position and leave it in that position until a sufficient amount of pressure has built up in the brake cylinder to give the retarding effect desired. The handle should then be moved to lap position. As the speed of the car is reduced, reduce the brake cylinder pressure in a series of steps by moving the valve handle from lap position to release position, and then back to lap position; repeat this movement until the stop is reached. At the point of stopping there should be only sufficient air in the brake cylinder to prevent the car rolling. It will be found that far better braking results will be obtained by making but one application as described above than by admitting only a small amount of air to the brake cylinder at the beginning of the stop, and increasing the pressure as the

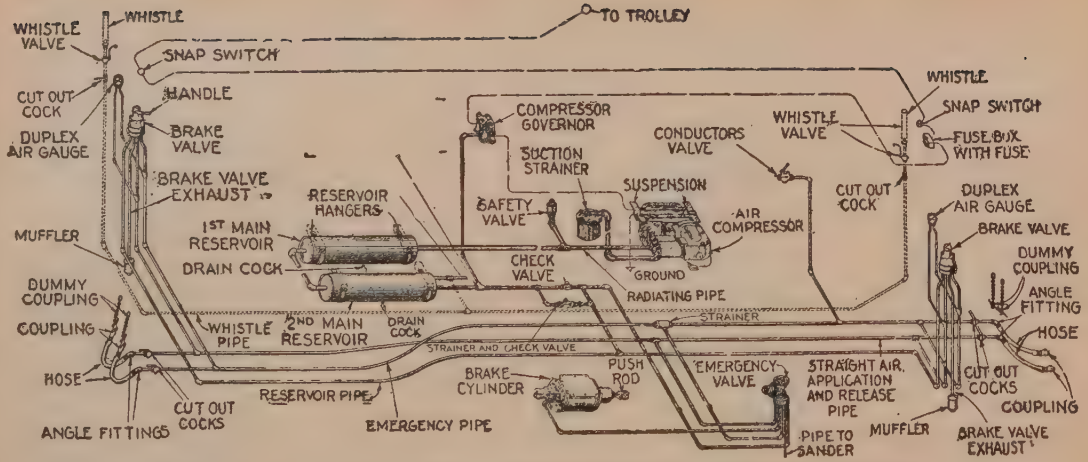


FIG. 6,304.—Westinghouse emergency straight air brake. Pictorial view showing parts and pipe connections.

speed of the car is decreased. The latter method usually results in rough stops, a waste of air and in many cases flat wheels. The practice of applying and releasing the brakes several times during a stop should be avoided.

Emergency stops: If it be desired to stop the car in the shortest possible distance, to avoid an accident, apply sand to the rails and at the same time move the motorman's valve handle to the emergency position and leave it in that position until the car comes to a stop or the danger be past.

Emergency Straight Air Brake.—An objection to the straight air brake is *the length of time required to apply the brakes owing to the relatively long pipe through which the air*

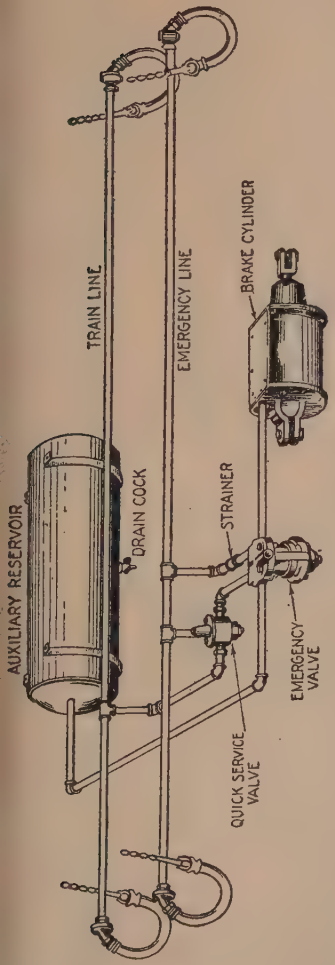


FIG. 6,305.—General Electric emergency straight air brake equipment for trail car.

must flow from the reservoir to the brake cylinder. This is especially objectionable when it is necessary to make a quick or emergency stop. A simple method of overcoming this defect is *by providing the straight air brake system with an emergency valve and an auxiliary reservoir pipe line*.

This arrangement is less complicated and costs less than the automatic system.

The various parts comprising the emergency straight air brake are shown with the pipe connections in fig. 6,304.

This equipment has been designed for cars which are normally operated as single units, but which under certain conditions are required to operate in short trains of two or more cars. These trains may consist of all motor cars or a combination of motor and trail cars. The equipment for a trail car is shown in fig. 6,305.

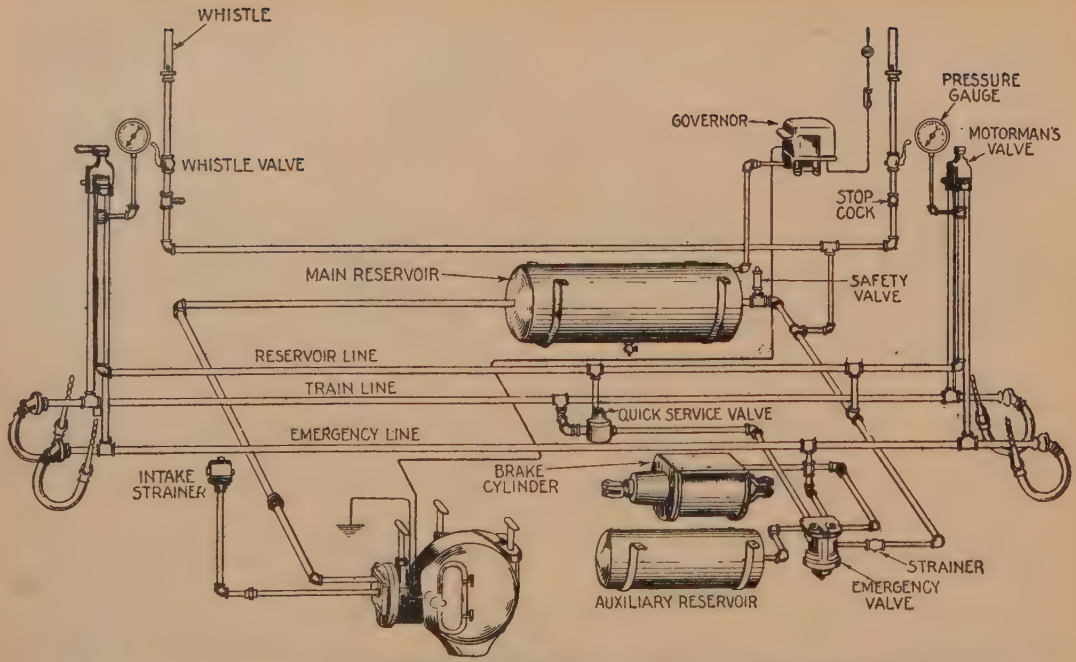


FIG. 6,306.—General Electric emergency straight air brake equipment for motor car. The emergency straight air brake equipment, as the name implies, is a combination of a straight air brake equipment and an automatic air brake equipment of the simplest form, the straight air brake equipment being used for service operation of the brakes and the automatic equipment for emergency operation. Two pipe lines, namely, the train line and the emergency line are installed the entire length of the train. The train line provides a direct connection from the motorman's valve to the brake cylinder on each car, thus serving the same purpose as

In operation when the valve is thrown into emergency position it allows the pressure of the reservoir line which is higher than that in the emergency valve to compress a spring in the latter and thereby allow a direct passage of reservoir air into the brake cylinder. Connections with the train line and reservoir lines are also simultaneously cut off. The application of the brakes on trailers is made possible by the addition of an auxiliary air reservoir, emergency valve, and reservoir line to the equipment necessary for "straight air" braking.

In order to release the brakes after an emergency application, the emergency valve must first be returned to its normal position by recharging the reservoir line to reservoir pressure, whereupon the brakes may be released as from a service application by exhausting the air from the train line.

Automatic Air Brake.—As previously mentioned the term automatic as applied to air brakes means that in case of accident such as the parting of a train, bursting of an air pipe, etc., the brake is automatically applied. To accomplish the automatic application of the brake in case of accident, it is necessary to provide on each car:

1. An auxiliary reservoir, and

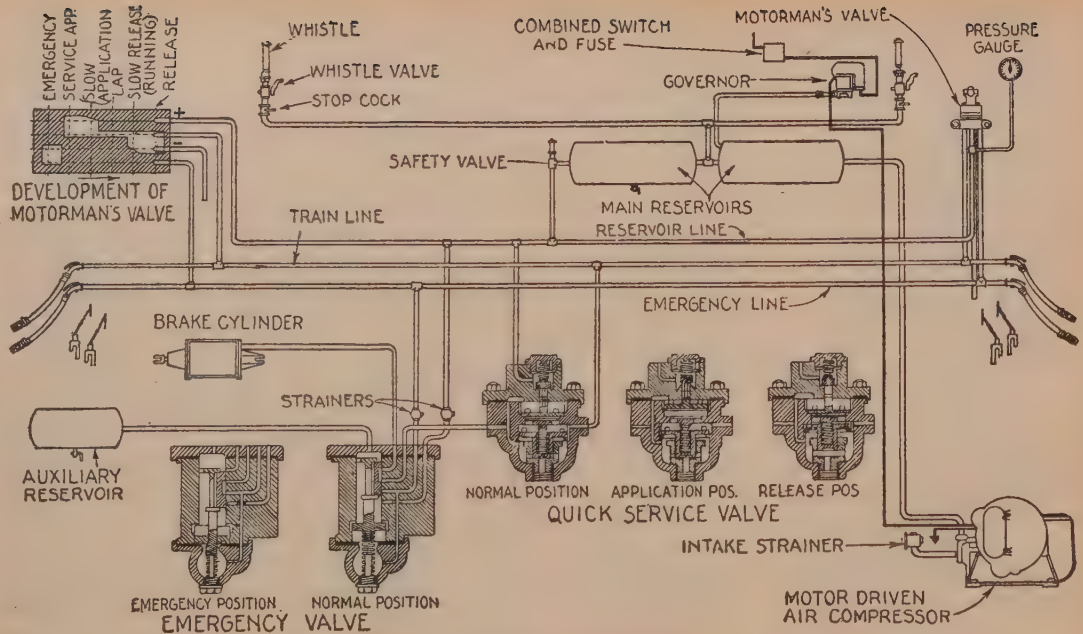
2. A triple or distributing valve.

The functions of the triple valve are briefly:

1. When charging and maintaining the pressure in the brake system:

1 ... 6,306—*Text continued.*

the train line in the straight air brake equipment. The emergency line normally carries air at reservoir pressure and connects together through the emergency valve the main reservoirs on the motor cars and the auxiliary reservoirs on the trail cars. Any sudden reduction of pressure in this emergency line applies the brakes automatically on each car of the train.



FIGS. 6,307 to 6,312.—Diagram showing General Electric emergency straight air brake. In this diagram, the actual construction of the motorman's valve at the left, the emergency valve and the quick service valve have been disregarded and these parts are shown diagrammatically, so that the passage of air through the same can be readily followed. The motorman's valve, although of rotary design, is shown at the left of the diagram, as a slide valve, so that the different positions and functions performed by the valve can be readily observed. It will be noted that in the *release position* of the valve, the train line is connected to atmosphere. In the *service application position*, the train line is connected to reservoir. In the *emergency position*, the emergency line is connected to atmosphere. The emergency valve is shown diagrammatically in the *normal position* and in the *emergency position*.

FIGS. 6,307 to 6,312.—*Text continued.*

It will be noted that, in the *normal position*, the train line is connected, through the quick service valve, by means of the cavity in the emergency valve slide valve, to the brake cylinder. Also the reservoir line is connected through the slide valve chamber to the auxiliary reservoir. In the *emergency position* of this valve, the auxiliary reservoir and brake cylinder are connected together and the train line and emergency line are connected together. The quick service valve is shown in three positions. In the *normal position*, the valve controlling the port from the train line to atmosphere is closed and the valve controlling the port from the reservoir to train line is closed. In the *application position*, the valve controlling the port from reservoir to train line, is open. In the *release position*, the valve controlling the port from train line to atmosphere is open. The operation is further described in the following notes.

NOTE.—***To make a service application*** of the brakes, the motorman's valve handle is moved to either the first or second *service application position*, depending on whether a quick or a graduated stop is desired. The valve handle is held in this position until the required brake cylinder pressure has been reached. It is then returned to the *lap position*. In the *service application position* air is admitted from the reservoir line by means of the motorman's valve to the train line raising the train line pressure. This causes the upper piston in the quick service valve to lift and the air from the train line then flows through leakage grooves past the piston through the cavity in the slide valve of the emergency valve to the brake cylinder. The movement of the piston of the quick service valve raises a lift valve from its seat which admits air direct from the reservoir line to the chamber above this piston, uniting with the train line air already flowing to the brake cylinder.

NOTE.—***To release the brakes*** after a service application, the motorman's valve is moved to the *release position*, thus connecting the train line to atmosphere as shown in the diagram. The reduction of train line pressure causes the lower piston with its direct connected valve in the quick service valve to raise, thus allowing the air from the brake cylinder to escape to atmosphere. Air from the brake cylinder also flows through the leakage grooves which are uncovered when this piston is raised, to the train line and through the motorman's valve to atmosphere. The passage of air through the quick service valve both in applying and releasing can be more clearly understood by referring to the *application* and *release position* of this valve shown in the diagram.

For an emergency application of the brakes, the motorman's valve is moved to the extreme right position which exhausts the air in the emergency line to atmosphere. This sudden reduction of pressure in the emergency line causes the piston in the emergency valve to move downward, due to the unbalanced pressure between the auxiliary reservoir and the emergency line until the lower edge of the piston makes an air tight joint on a leather gasket at the bottom of the piston chamber. This cuts off any flow of air from the auxiliary reservoir to the emergency line, and therefore prevents the auxiliary reservoir air escaping to atmosphere through an open emergency line. With the emergency valve in this position, communication is established between the auxiliary reservoir and brake cylinder. Connection is also made between the emergency line and the train line, the object being to afford an additional exhaust to atmosphere from the emergency line in case the train line is open between the cars. This connection between the emergency line and train line in the emergency position of the valve, provides a means for releasing the brakes after an emergency application has been made.

NOTE.—***To release the brakes*** after an emergency application, the motorman's valve is moved to the service application position, so that the emergency line will be charged through the train line and the slide valve in the emergency valve will be forced to its normal position. The motorman's valve is then moved to the release position which exhausts the brake cylinder to atmosphere.

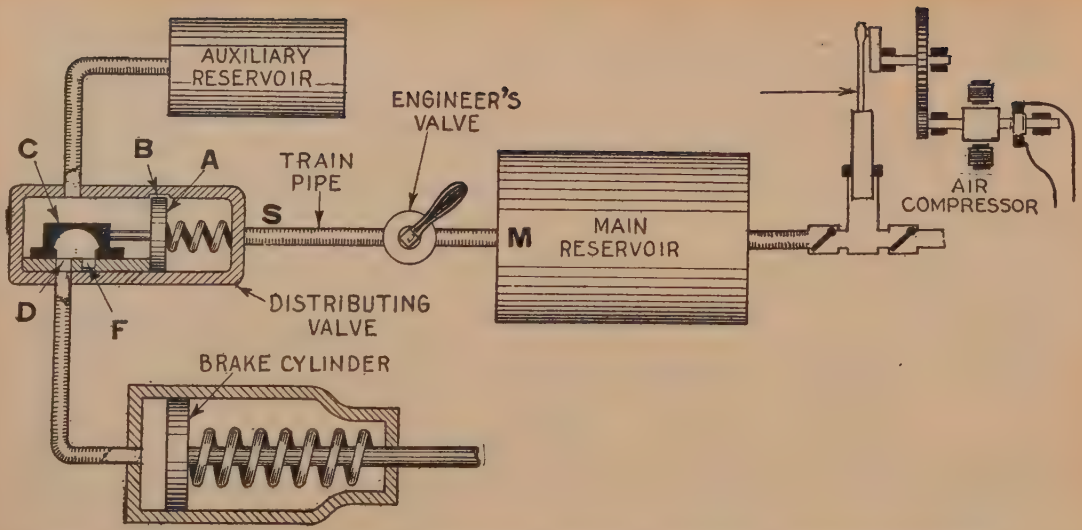


FIG. 6,313.—Elementary automatic air brake. The principles of operation are described in the accompanying text

a. To permit air to flow from the brake pipe to the auxiliary reservoir;

b. To prevent air flowing from the auxiliary reservoir to the brake cylinder;

c. To keep the brake cylinder open to the atmosphere.

2. When applying the brakes:

a. To close communication from the brake pipe to the auxiliary reservoir.

3. When holding the brakes applied:

a. To close all communication between the brake pipe, auxiliary reservoir, brake cylinder and atmosphere.

4. When releasing the brakes and recharging the system:

a. To open communication from the brake cylinder to the atmosphere;
b. To permit air to flow from the brake pipe to the auxiliary reservoir;
c. To prevent air flowing from auxiliary reservoir to the brake cylinder.

The operation of the system is best explained by first considering the elementary arrangement shown in fig. 6,313, illustrating the principles of operation.

Here, the air pump maintains a supply of compressed air in the main reservoir at a suitable pressure. The engineer's valve may be turned 1, so as to establish communication between the main reservoir and the train pipe; 2, this communication may be broken and the air locked in the two parts of the system; 3, the opening from the main reservoir may be closed and that from the train pipe opened into the atmosphere. Air passes through the distributing valve to the auxiliary reservoir placed under each car. The distributing valve also affords communication between the auxiliary reservoir and the brake cylinder when the brakes are to be applied.

In operation, the pump maintains a supply of compressed air of suitable pressure in the main reservoir. Opening the engineer's valve allows air to flow through train pipe, to distributing valve; entering this it comes in contact with piston A, and pushes it to the left end of its stroke. When in this position, one side of the piston is spanned by the groove B, in the casing, called the leakage groove. Air leaks through this groove into the space behind the piston and thence passes into the auxiliary reservoir.

When the pressure in auxiliary reservoir and train pipe becomes equalized, the apparatus is said to be charged and the brakes can be applied by turning the engineer's valve so that the flow from the main reservoir is stopped and the air in the train pipe is exhausted into the atmosphere; this causes excess pressure on left face of piston A. The air then starts to rush out from auxiliary reservoir through leakage groove, but as it cannot escape rapidly enough to supply the loss in D, the piston A, is moved to the right moving

with it the attached slide valve C, which uncovers the port D, leading to the brake cylinder. This allows air to flow into the brake cylinder and apply the brake. Meanwhile the piston A, has traveled to the right, and beyond the end of the leakage groove B, stopping the flow of air from the auxiliary reservoir to the train pipe, thus setting the brakes; they will remain set until released.

To release brakes the engineer reestablishes communication between the main reservoir M and the train pipe S. Air again enters the triple valve. The piston A, is pushed to the left, thus C, is shifted so air flowing from

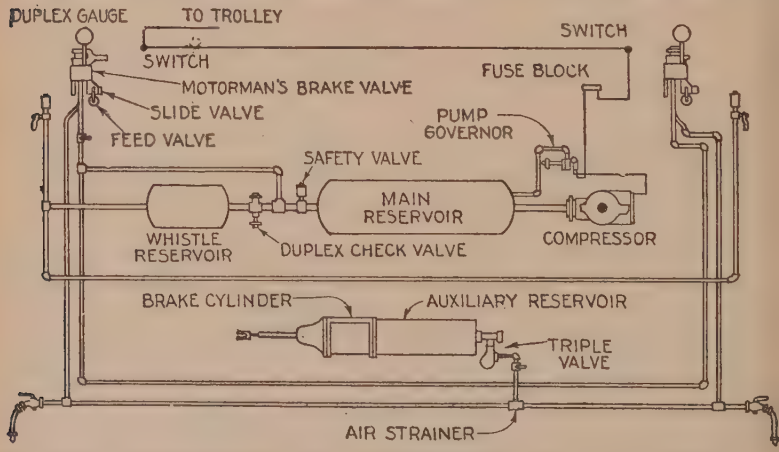


FIG. 6,314.—Automatic air brake system showing essential parts and pipe connection

auxiliary reservoir into the brake cylinder is stopped and the brake cylinder vented to atmosphere by means of the passage beneath valve which connects port D, and exhaust port F, the latter being open to the atmosphere.

The elementary principle here presented should be thoroughly understood before making a study of the actual apparatus.

The essential parts of the automatic air brake are shown with the pipe connection for a double ender installation in fig 6,314.

Automatic Variable Release Air Brake.—This is a type o

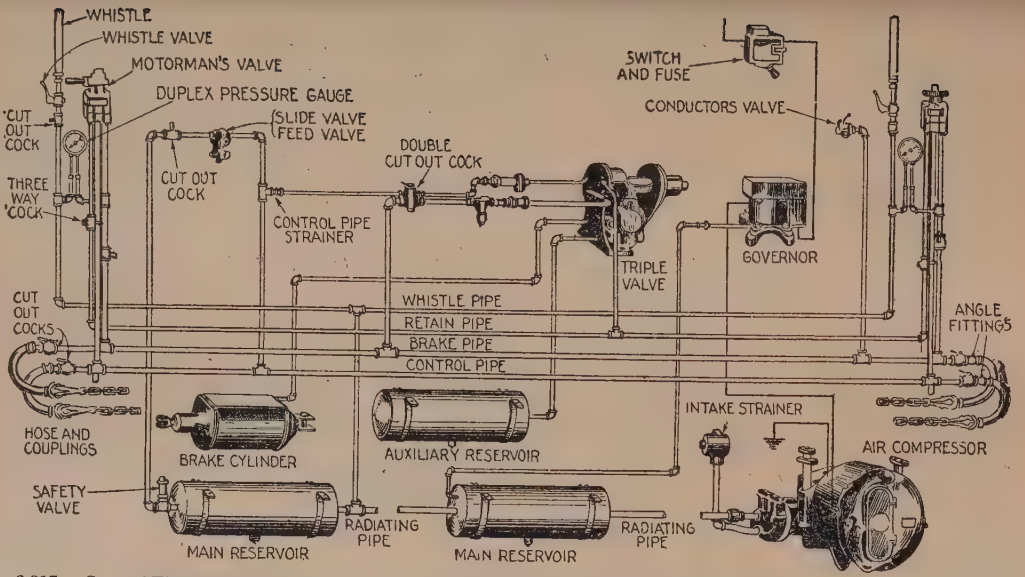


FIG. 6,315.—General Electric automatic variable release air brake equipment for motor car, showing parts and pipe connections.

automatic brake *provided with a triple valve designed to give a full or restricted release of the brakes as desired*. This feature is useful in obtaining the accurate stops so important in stations where individual cars are required to stop opposite certain definite points. Less air is also used, since it is necessary to make only one application when

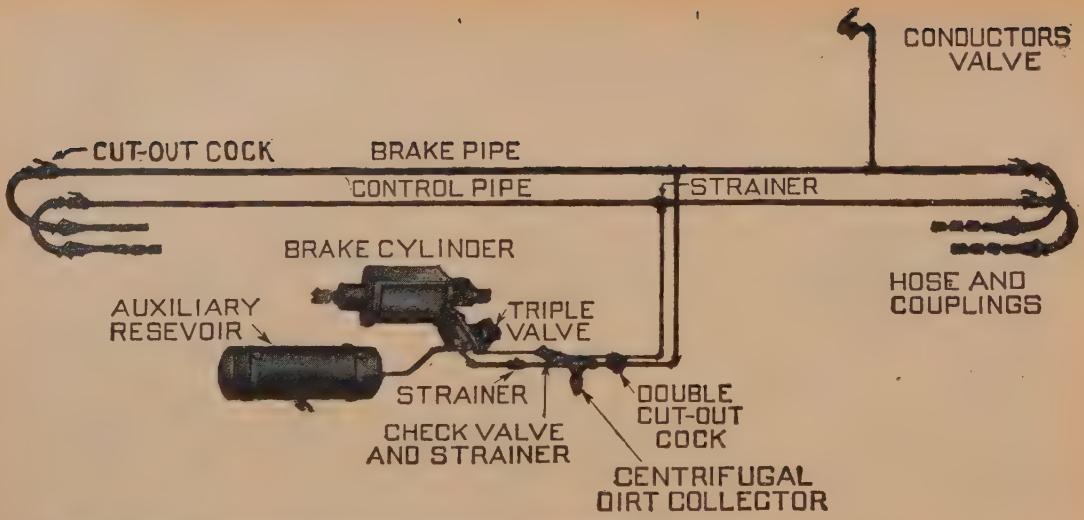


FIG. 6,316.—General Electric automatic variable release air brake equipment for trail car.

approaching a station, the brake cylinder pressure then being reduced in a series of steps as the speed of the train is decreased.

The general arrangement of the equipment is shown in fig. 6,315.

In operation the air from the main reservoir is admitted directly to the control pipe on each motor car, through a feed valve adjusted to reduce the reservoir pressure of 85 or 95 lbs. to the standard brake pipe pressure of 70 lbs. The excess pressure is thus confined to the main reservoir and the danger of overcharging the brake pipe and auxiliary reservoir is consequently eliminated.

On account of the fact that the pressures above and below the rotary valve of the motorman's valve are equalized, when in the release and running positions the motorman's valve operates very easily, thus minimizing wear on the rotary valve and seat.

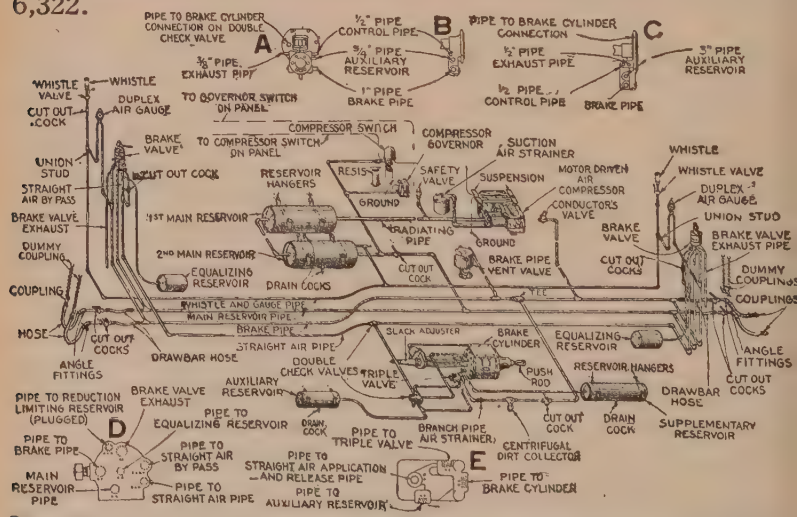
This arrangement has the further advantage of providing automatically for an even distribution of work between the several compressors on a train, without the use of special governing apparatus. The triple valve is of the quick acting, quick recharge, variable release type, which recharges the auxiliary reservoir directly from the control pipe on each car.

Quick Acting Automatic Air Brake.—This type of automatic air brake *is the same as the plain automatic but with the additional feature that the triple valve is so modified that when a relatively quick reduction in brake pipe pressure is made, it also opens a direct communication from the brake pipe through the triple valve to the brake cylinder.* This not only increases the brake cylinder pressure in proportion to the amount of air flowing into it from the brake pipe, but by venting air from the brake pipe locally on each car, hastens and increases the effect of the reduction made at the brake valve; the net result being to greatly shorten the time from the movement of the brake valve handle until a full brake application is obtained on the entire train, and to increase the total braking power obtainable by such operation (called an emergency application of the brakes), about 20 per cent over the maximum obtainable during ordinary operations (called service applications of the brake), or when using the plain automatic brake. This difference is due solely to the construction of the triple valves, which are called respectively the plain and quick action triple valve.

For all ordinary (service) applications of the brake, the operation of the two triple valves is identical.

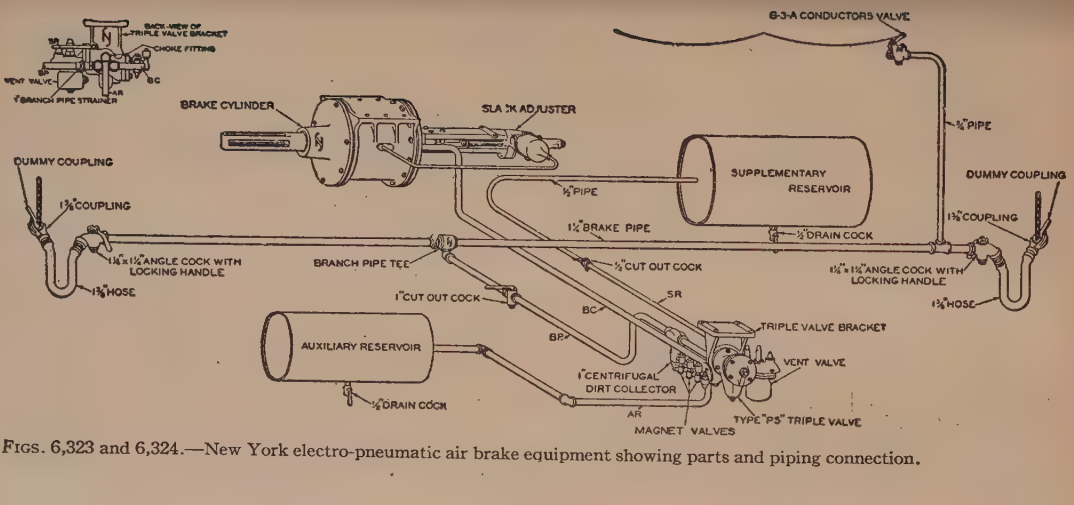
Combined Automatic and Straight Air Brake.—This equipment is designed for use on electrically operated vehicles running in single car service or in trains. It is therefore especially

adapted for both city and high speed interurban train service as well as for such service as is required of light electric locomotives or motor cars used for handling freight cars, switching, etc., since it provides for quick and flexible operation of the brakes on a single unit by straight air with the added facility of immediately changing to automatic operation when coupled to cars. This system as constructed, is shown in figs. 6,317 to 6,322.



FIGS. 6,317 to 6,322.—Westinghouse combined automatic and straight air brake equipment diagrams showing parts and pipe connections. Figs. A, B, C, show pipe connections to brake cylinder pressure head; fig. D, pipe bracket of brake valve; fig. E, pipe double check valve.

Electro-pneumatic Air Brake.—On account of the changing conditions of railroad service such as longer trains, heavier cars, higher speed, greater frequency of trains, stops, etc., new functions and additional refinements are demanded of air brake equipments. To meet these exacting conditions the electro-pneumatic system of brake control has been developed. The operation of this system depends on *a triple valve so constructed*



FIGS. 6,323 and 6,324.—New York electro-pneumatic air brake equipment showing parts and piping connection.

that the air distribution which causes it to operate may be controlled either pneumatically or electrically.

The Westinghouse electro-pneumatic brake equipment as applied to the Staten Island Rapid Transit Railway and the Philadelphia subway, and here described, illustrates electro-pneumatic control of brakes.

The equipment consists of the following parts: as shown in figs. 6,325 to 6,332.

1. Motor driven air compressor.

To compress the air.

2. Electric compressor governor.

This in conjunction with the *compressor switch*, automatically controls the operation of the compressor between predetermined minimum and maximum pressures.

3. Two main reservoirs.

These receive the compressed air from the air compressor for use in charging the brake system. They also supply air to the brake cylinder in emergency applications to produce a high emergency pressure.

4. Safety valve.

This connected to the main reservoir protects against excessive main reservoir pressure should the governor for any reason fail to operate properly.

5. Auxiliary reservoir.

This supplies air to the brake cylinder in service applications.

6. Supplementary reservoir.

This assists in obtaining graduated release of the brakes and prompt recharging of the equipment.

7. Feed valve.

This automatically maintains a predetermined normal pressure in the system.

8. Two illuminated duplex air gauges.

One connected to the piping near each brake valve, which shows by a red hand the pressure in the main reservoirs, and by a black hand the pressure of the brake pipe.

9. Two brake valves.

One at each end of the car by which the motorman by proper manipulation of the handle, can operate the brakes on each car.

10. Two equalizing reservoirs.

One at each end of the car, which are required for the operation of the equalizing piston of the brake valves.

11. Universal valve.

It corresponds in a general way to the triple valve in common use, operates to charge the reservoirs and to control the admission of air to, and exhaust from, the brake cylinder.

12. Brake cylinder.

This is provided with piston and rod so connected through the brake levers and rods to the brake shoes that when the piston is forced outward by the air pressure, this force is transmitted through the rods and levers to the brake shoes and applies them to the wheels.

13. Brake cylinder pressure limiting valve.

This is located in main reservoir pipe to limit brake cylinder pressure in emergency application to the valve's adjustment, in this case 60 lbs.

14. Conductor's valve.

Located inside each car, whereby the conductor may apply the brakes if necessary.

15. Combination double and single cut out cock.

Located in the brake pipe and main reservoir pipe branches with a connection to the brake cylinder and equipped with extension handles with which it is possible to open and close the cocks from the interior of the car.

16. Three plug switch.

Used to establish the electrical supply circuit to the operating brake valve.

17. Two air alarm whistles.

While not a part of the air brake apparatus proper, one of these whistles is placed at each end of the car with the necessary whistle valves and cut out cocks to be used as a warning of approach.

18. Various cut out cocks, air strainers, check valves, hose, switches, etc.

19. Automatic slack adjuster.

By means of this a predetermined piston travel and consequently a uniform cylinder pressure is constantly maintained, compelling the brakes on each car to do their full share of the work, thus securing the highest efficiency and reducing the danger of flat wheels which are likely to accompany a wide range of piston travel. This device establishes the running piston travel; that is, the piston travel, occurring when the brakes are applied while the car is in motion; and since this is the time during which the brakes perform their work, the running travel is most important.

With this equipment four lines of pipe are used: *feed valve pipe*, *feed valve control pipe*, *main reservoir pipe* and *brake pipe*, the main reservoir pipe and brake pipe being continuous throughout the train.

The *feed valve pipe* is always kept charged to the pressure, determined by the setting of the feed valve and furnishes the air supply to the controlling brake valve.

The *feed valve control pipe* connects brake pipe pressure through the brake valve to the feed valve so that the actual pressure of the brake pipe controls

the opening and closing of the feed valve, thus assuring consistent operation of the feed valve to maintain a fully charged brake system.

The *main reservoir pipe* has a branch to the universal valve on each car through which main reservoir pressure is supplied to the brake cylinder in emergency application.

The *brake pipe* connects the controlling brake valve to the universal valves throughout the train and forms the means of communication by which the motorman by proper manipulation of the brake valve handle can operate the brakes on each car.

Rules for Operating Electro-pneumatic Air Brakes.—The following rules are intended to cover in a condensed form the important instructions to be observed in handling this equipment in service.

Charging.—Before starting the air compressor, *close* the drain cocks in the main, auxiliary and supplementary reservoirs, the brake pipe and main reservoir pipe cut out cocks at each end of the train (or car) and all whistle cut out cocks except the one in the operator's cab.

See that the following cocks are *open*: The main reservoir cut out cock between the main reservoir and feed valve, both cocks of the combined cut out cock, one of which is in the brake pipe branch pipe to the universal valve and the other in the main reservoir pipe branch pipe to the universal valve, all brake pipe and main reservoir pipe cut out cocks, between cars and the whistle cut out cock in the operator's cab.

See that all hand brakes are fully released.

The fuses in the compressor and battery circuits must be in place and *live*. Place a handle on the brake valve to be operated and move it to *release and running* position at the extreme left; also insert plug of three pole switch at the brake valve. Then close the snap switch in the battery circuit and start the compressor by closing the snap switches in the compressor circuits.

Do not attempt to move the train (or car) until the brake pipe gauge hand shows full brake pipe pressure.

Running.—Keep the brake valve handle in *release and running* position when not being used. In event of sudden danger,

move the brake valve handle quickly to *emergency* position at the extreme right and leave it there until the train stops and the danger is past.

If the brakes apply while running over the road, due to the opening of the conductor's valve or rupture of the brake pipe, move the brake valve handle to *lap* position at once to prevent loss of main reservoir pressure. After the train stops, the cause of the application should be located and remedied before proceeding.

Service Application.—To apply the brakes for an ordinary stop, move the brake valve handle to *service* position. When the brake pipe gauge hand shows that a sufficient reduction in brake pipe pressure has been made to apply the brakes as required by the speed, condition of rail, grade, loading and kind of stop desired, move the handle back to *lap* or *holding* position, according to the results desired, as explained later, where it should remain until it be desired either to release the brakes or to apply them with greater force.

In the latter case move the handle again to *service* position, further reducing the brake pipe pressure until the desired result be obtained, then return it to *lap* or *holding* position.

The amount of brake pipe reduction necessary in any given case depends entirely on the conditions as stated above, a knowledge of which is soon acquired by practice. It should be especially borne in mind, however, that the retarding effect of any given reduction is relatively greater at low than at high speeds, other conditions being equal.

When making a pneumatic service application, it is useless to attempt a reduction below the equalizing point, at which the auxiliary reservoir and brake cylinder pressure become equal, as no further increase in brake cylinder pressure can be obtained. Furthermore, this results in a delayed release and a waste of air.

Under normal operating conditions an equalizing point corresponds to a reduction of 20 lbs. from 70 lbs. brake pipe pressure. The brake pipe reduction is automatically limited when operating electrically upon equalizing of the brake pipe and brake cylinder pressure.

The best possible stop will be made when the brakes are applied as hard, *at the very start*, as the conditions of speed, rail and comfort of passengers will

permit, and then graduated off as the speed of the train is reduced, so that at the end of the stop little or no pressure remains in the brake cylinders.

Because the retarding effect of any given reduction is greater at low than at high speed, a heavy brake pipe reduction at low speeds will result in an abrupt stop, with perhaps discomfort to passengers or slid wheels. At high speeds a heavy initial reduction should be made in order to obtain the most effective reduction possible when the momentum of the train is greatest. If the brake cylinder pressure be very light at first and be increased as the speed of the train diminishes, it not only makes a longer stop but the high cylinder pressure at the end will be liable to produce a rough stop, perhaps slide the wheels and result in loss of time because of the necessity for waiting until this high cylinder pressure can exhaust before the train can proceed.

Holding the Brakes Applied.—After the reduction of brake pipe pressure has been made, the brake valve handle should be placed in lap position when operating *pneumatically* and left there until it be desired to make a further reduction or to release the brakes. When operating *electrically*, the brake valve handle should be placed in *holding* position if it be desired to recharge the system while holding the brakes applied.

Never allow the brake valve handle to remain in lap or holding position, except while bringing the train to a stop, and it should not be allowed to remain in this position for a sufficient length of time to permit the cylinder leakage to diminish the braking power materially.

Release.—*To fully release the brakes* after any application, move the brake handle to *release* and *running* position. The handle must be left in this position at all times when the brakes are not in use.

Electric. *To graduate or partially release the brakes*, move the brake valve handle to *release and running* position for a moment, then back to *holding* position; repeat this operation as may be necessary until the train is brought to rest with only enough pressure retained in the brake cylinders to prevent its rolling.

Pneumatic. *To graduate or partially release the brakes*, move the brake valve handle momentarily to *release and running* or to *holding* position, then back to *handle off* or *lap* position; repeat this operation as may be

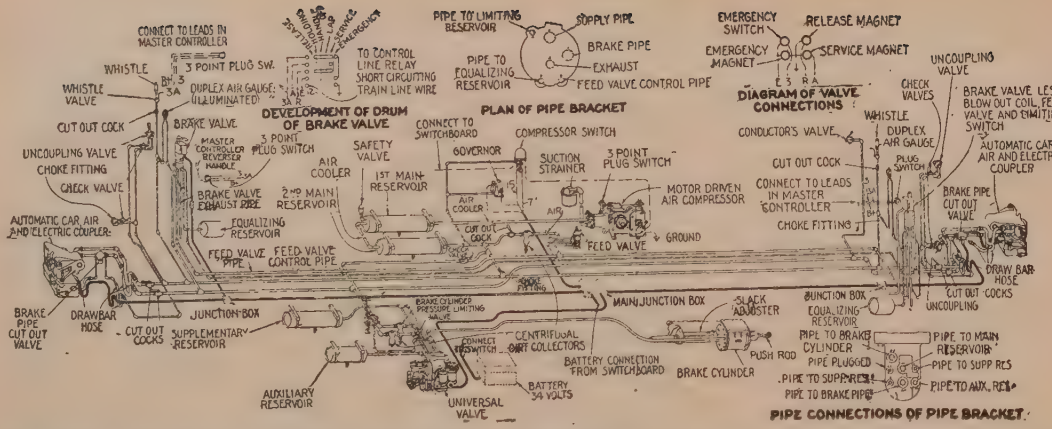
necessary until the train is brought to rest, only enough pressure being retained in the brake cylinders at the end of the stop to prevent the wheels rolling. With very little practice, the motorman will learn how long the handle should remain in *release and running* or *holding* position to produce the results desired. Obviously, this varies with the brake cylinder pressure, the amount of reduction in brake cylinder pressure desired and the length of train, etc.

When it be desired to release the brakes but slightly or when handling short trains, if the handle be moved to *release and running position*, the resulting increase in brake pipe pressure and the corresponding release of brake cylinder pressure is likely to be greater than is intended. For this reason it is usually best in such cases to move the handle from *lap* to *holding* instead of to *release* and *running position*. A few trials will enable the motorman to find out for himself which of the two positions he should use.

Emergency.—Should it become imperative to stop in the shortest possible time and distance, to save life or avoid accident, move the handle quickly from whatever position it may be in to *emergency position*, which is at the extreme right, and leave it there until the train stops and the danger is past.

Changing Ends.—When changing from one end of the train or car to the other, close the whistle cut out cock, remove the brake valve handle, withdraw plug of three pole switch and, after placing the handle on the brake valve at the other end and inserting the switch plug, move the handle to *release* and *running position* and open the whistle cut out cock in the operator's cab.

Synchronizing System.—The compressor governor, compressor switch and a wire, extending throughout the train, designated the synchronizing wire, comprise what is termed the synchronizing system, the purpose of which is to insure that all compressors in the train will start and stop at the same time, thus equally dividing compressor labor and eliminating overwork on the part of any single compressor.



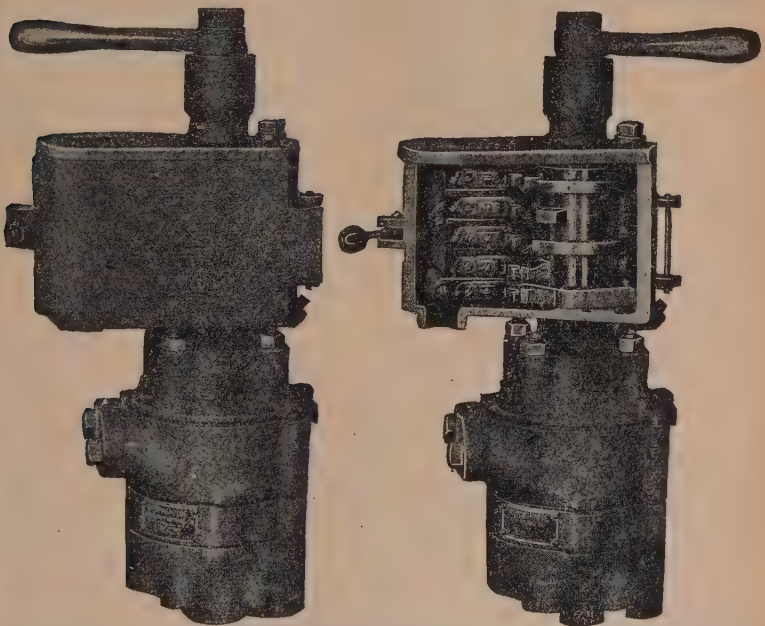
FIGS. 6,325 to 6,332.—Piping and wiring diagrams of Westinghouse electro-pneumatic brake equipment as applied to the motor cars of the Staten Island Rapid Transit Railway Co. B+, + battery wire; 15, synchronizing wire; 3, emergency switch wire; R, release wire; A, application wire; E, emergency wire; 7, – battery wire.

All governor terminals are connected in parallel between the synchronizing wire and the positive side of the battery, all compressor switch magnet terminals between the synchronizing wire and the negative side of the battery, as shown in fig. 6,330.

When any master governor cuts in, the magnets of all compressor switches in the train are energized, the magnets in turn operating valves to cut in the switches thus completing the circuit from trolley to compressor on each car.

Electro-pneumatic brake valve handle positions.—The handle positions from left to right are

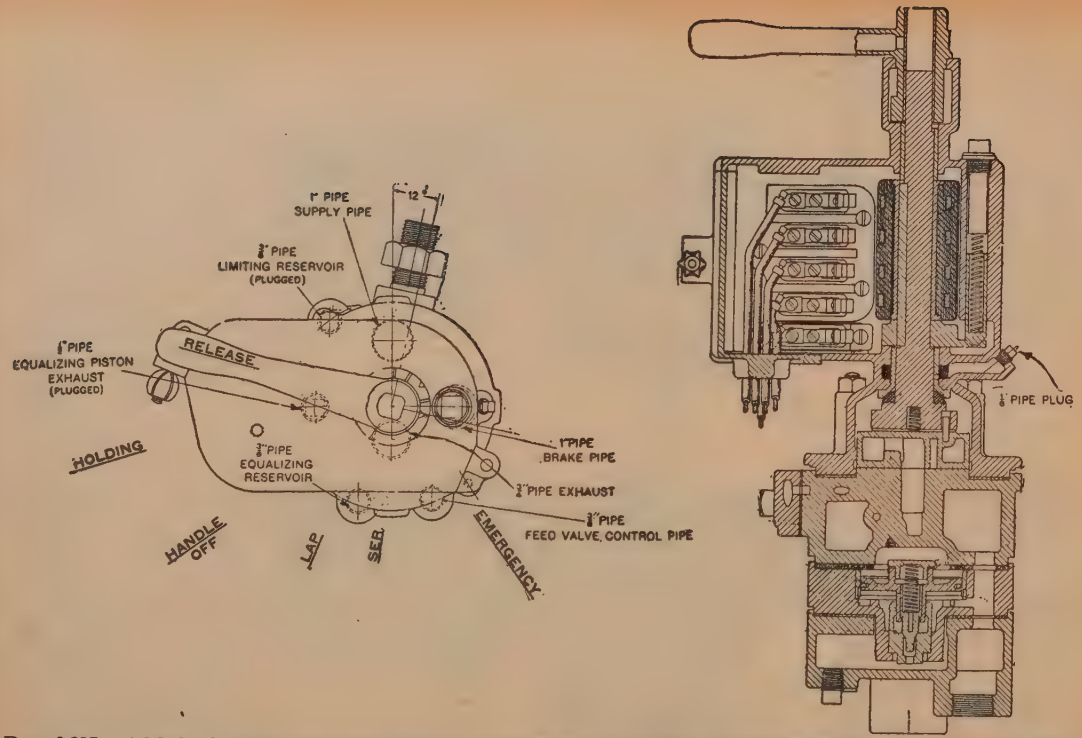
1. Release.
2. Electric holding.
3. Handle off.



FIGS. 6,333 and 6,334.—Westinghouse electro-pneumatic brake valve. Fig. 6,333, view with cover in place; fig. 6,334, view with cover removed showing electric portion.

4. Lap.
5. Service.
6. Emergency.

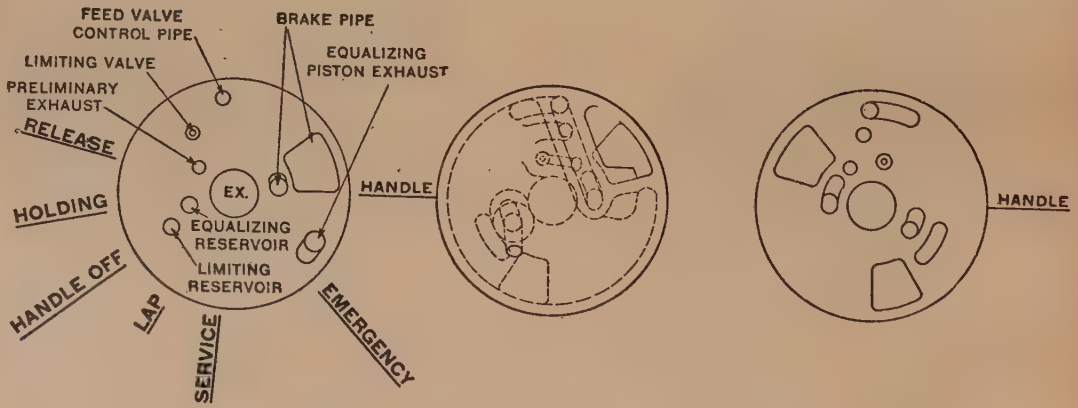
The pneumatic portion of the brake valve is shown diagrammatically in figs. 6,340 and 6,350. The electric portion is shown in fig. 6,334, and



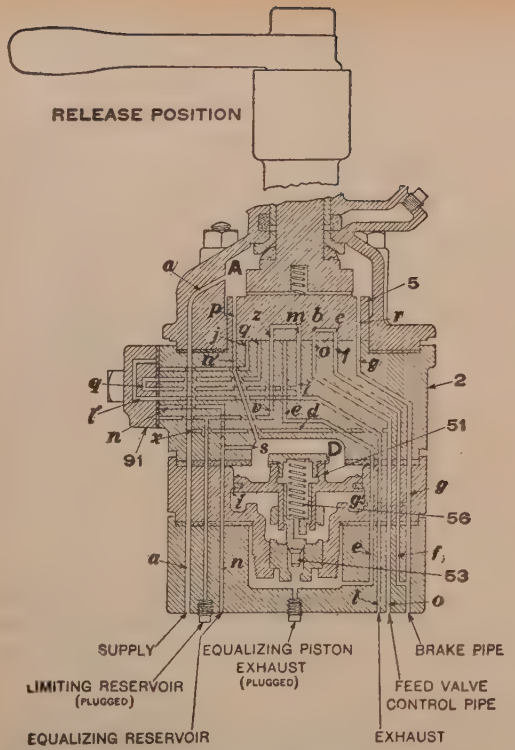
FIGS. 6,335 and 6,336.—Westinghouse electro-pneumatic brake valve. Fig. 6,335, top view showing various positions; fig. 6,336, sectional view. ***In construction***, seven connections are provided on the bracket as follows: Supply pipe, brake pipe, feed valve control pipe, equalizing reservoir, brake valve exhaust, equalizing piston exhaust and limiting reservoir, the last two of which are

FIGS. 6,335 and 6,336.—*Text continued.*

not used and therefore are plugged. Raised letters are cast on the bottom of the pipe bracket to insure that proper connections are made. This brake valve is composed of two distinct parts, one pneumatic and the other electric. The electric portion is placed above the pneumatic and consists of a rotary drum with contacts attached to the same shaft as the rotary valve and corresponding fingers on the body of the valve. The upper finger is connected to the supply wire and to the emergency switch wire through the three pole switch, as shown in fig. 6,326, the second to the service magnet wire, the third to the release magnet wire, the fourth to the emergency magnet wire and the bottom one to the control line relay short circuiting train line wire. This last finger provides an emergency protection feature which is further described under the heading *emergency position*. The positions of the handle are identical for the electric and pneumatic release, service and emergency, consequently, if the electric control should fail, the pneumatic control will automatically function.



FIGS. 6,337 to 6,339.—Westinghouse electro-pneumatic rotary valve and seat of the brake valve. Fig. 6,337, plan of rotary valve seat; fig. 6,338 plan of rotary valve; fig. 6,339, face of rotary valve.



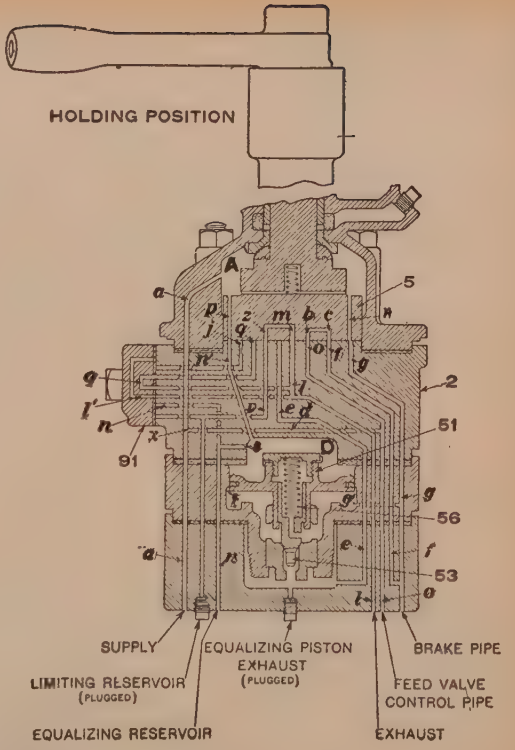


FIG. 6,340.—Westinghouse electro-pneumatic brake valve 1. Release position.
FIG. 6,341.—Westinghouse electro-pneumatic brake valve 2. Holding position.

diagrammatically in fig. 6,326. The operation of the brake valve in the various positions is as follows:

Release position.—Fig. 6,340. All brakes throughout the train are released and the system recharged. The feed valve pipe supplies feed valve pressure through passage *a*, to chamber *A*, above the rotary valve whence the pressure flow continues through port *r*, and passage *g*, to the brake pipe and through port *p*, and passage *b'*, to chamber *D*, and passage *S*, charging the brake pipe and equalizing reservoir to feed valve pressure. The chamber beneath the equalizing piston is charged through passage *g'*.

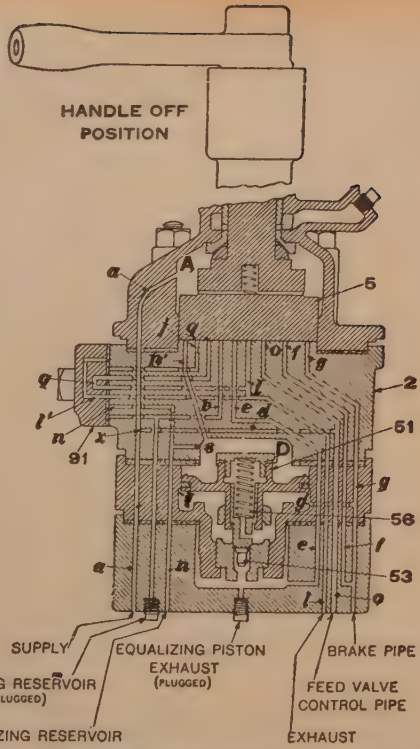
Ports *b*, and *c*, are connected, establishing communication between passages *f*, and *o*, allowing brake pipe pressure to flow from passage *g*, through the feed valve control pipe back to the diaphragm regulating chamber of the feed valve. No electrical connection is made in this position. Therefore, the release magnets on the universal valves are de-energized, permitting the escape of brake cylinder air to the atmosphere. The service and emergency magnets are held, closed by their respective springs.

Electric holding position.—In fig. 6,341, pneumatically the same operation takes place as in *release position*, except the recharge is slower due to the fact that port *r*, is not fully open.

Electrically, the release magnets are energized, thus preventing the exhaust of brake cylinder air. Therefore, in this position the brakes may be held applied while the brake pipe is being recharged or if desired, graduated off by movement of the brake valve handle between *release* and *holding positions*.

Handle off position.—Fig. 6,342. This position permits removal of the handle. The rotary valve blanks the ports and therefore the brakes are held applied as the brake pipe pressure has not been restored after the service reduction that should always precede removal of the handle.

Electrically, the release magnets are energized so that brake cylinder pressure will not be lost in case the brake valve handle be placed by mistake in this position when *lap* is intended or in passing from *lap* to *holding* as just before graduating the release. Restricted opening *x*, in passage *d*, of the rotary seat maintains communication between the feed valve supply, *a*, and the feed valve control passage *o*, so that when both brake valve handles on a car are in handle off position, at which time *f*, and *o*, will be blanked by the rotary valve, any leakage from the feed valve supply pipe will be reflected in the control pipe, which will cause the feed valve to open to maintain the pressure above the rotary valve, keeping the rotary valve on its seat and assuring a head pressure to effect a quick recharge on return of the handle to release.



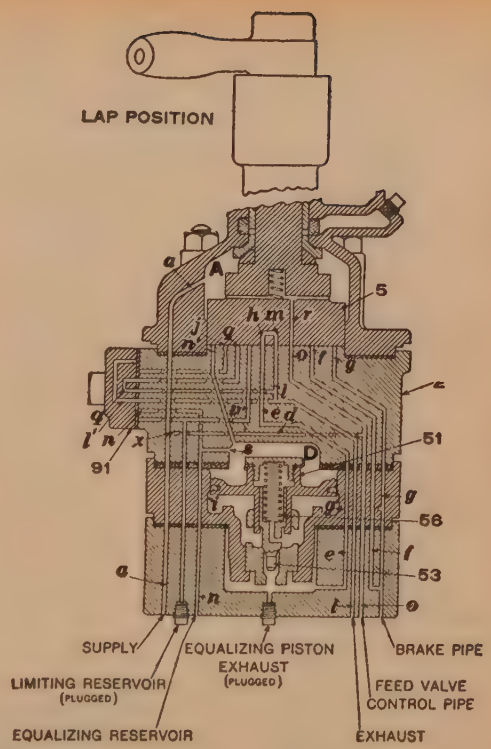
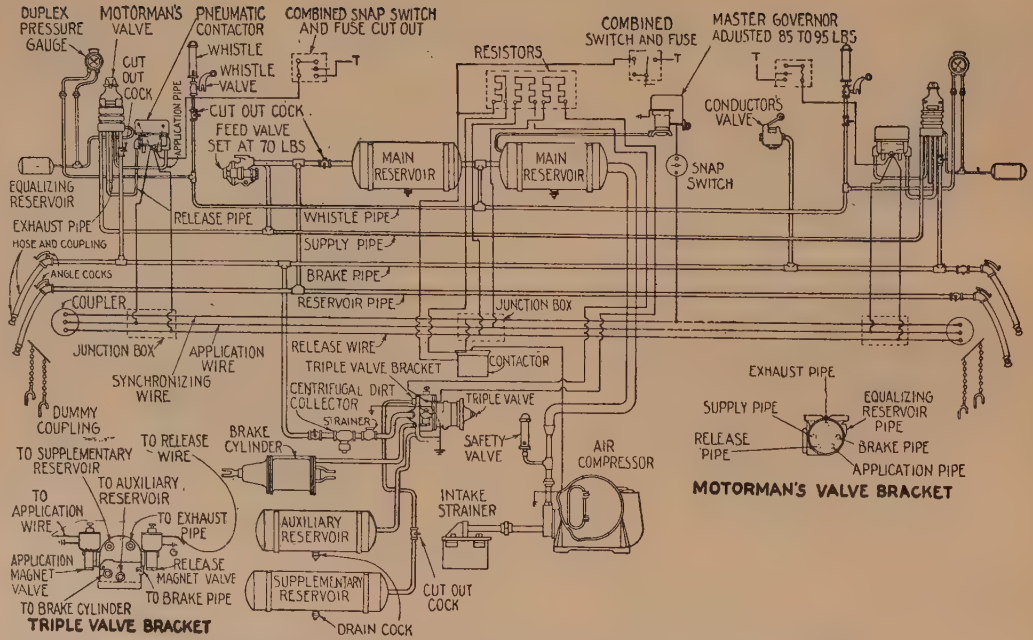
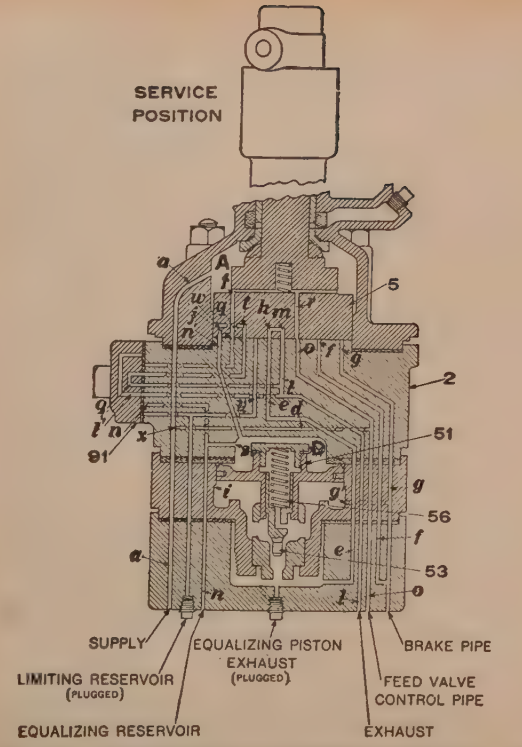


FIG. 6,342.—Westinghouse electro-pneumatic brake valve 3. Handle off position.
FIG. 6,343.—Westinghouse electro-pneumatic brake valve 4. Lap position.



FIGS. 6,344 to 6,348.—General Electric connections for electro-pneumatic motor car air brake equipment.



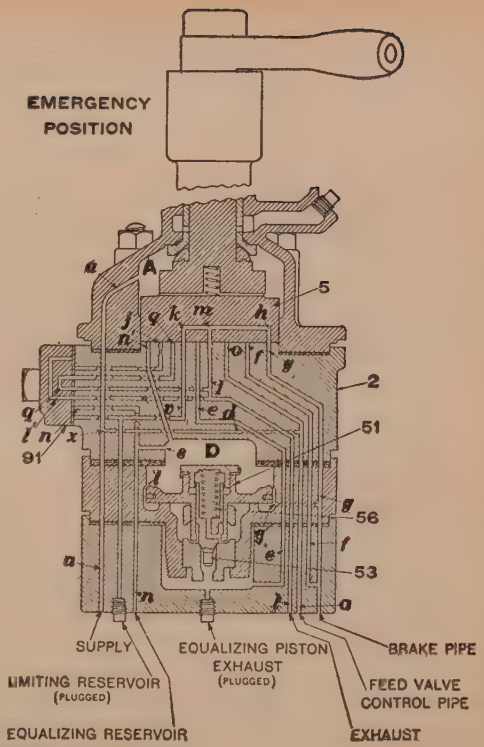


FIG. 6,349.—Westinghouse electro-pneumatic brake valve 5. Service position.
FIG. 6,350.—Westinghouse electro-pneumatic brake valve 6. Emergency position.

Lap position.—Fig. 6,343. This position is used to hold brake cylinder pressure and therefore all ports are closed except the equalizing discharge valve exhaust port *e*, which is connected to the exhaust port *l*, through ports *h* and *m*, in the rotary valve. Brake pipe exhaust from the equalizing discharge valve, 53, through passage *e*, therefore is open to the brake valve exhaust so that brake pipe pressure can be pulled down equal to the equalizing reservoir reduction of the preceding brake pipe reduction. Also, supply pressure in chamber *A*, is maintained to feed valve setting due to the control exercised by port *r*, communicating with the feed valve control pipe through passage *o*. Release magnets are energized to hold brake cylinder pressure.

Service position.—Fig. 6,349. All brakes are applied throughout the train. Pneumatically, ports *w*, and *t*, in the rotary valve register with ports *n'* and *q*, in the seat, allowing air from chamber *D*, and the equalizing reservoir to escape through passage *l*, to the atmosphere. The fall of pressure in chamber *D*, allows the brake pipe pressure under the equalizing piston 51, to raise it and unseat the discharge valve, 53, permitting brake pipe air to flow to atmosphere from passage *g*, through passage *g'*, past the discharge valve, through passage *e*, in the seat, ports *h* and *m*, in the rotary valve and *l*, in the seat to the brake valve exhaust. Also, port *r*, in the rotary valve is slightly open to permit communication between the control pipe and the supply pipe thereby maintaining supply pressure at the maximum.

When the pressure in chamber *D*, is reduced the desired amount, the handle is moved to *lap position*, thus stopping any further reduction from that chamber. Air will continue to discharge from the brake pipe past the discharge valve until the pressure has dropped to an amount slightly less than that retained in chamber *D*, when the piston will be forced downward gradually, the discharge valve seating and stopping the discharge of brake pipe air.

It will be apparent that the amount of reduction in the equalizing reservoir determines that in the brake pipe, regardless of the length of the train. The gradual reduction in brake pipe pressure is to prevent quick action, and the gradual stopping of discharge to prevent the pressures at the head end of the brake pipe being built up by air flowing from the rear which might cause some of the head brakes to *kick off*.

Electrically, the release magnets and service magnets throughout the train are energized, thereby closing brake cylinder exhaust and producing an electric service brake application.

Emergency position.—Fig. 6,350. All brakes are quickly and fully applied throughout the train. Pneumatically, the brake pipe passage *g*, is directly connected through fully opened ports, *h*, and *m*, in the rotary valve to the exhaust port *l*, a heavy reduction of brake pipe pressure thereby being quickly obtained.

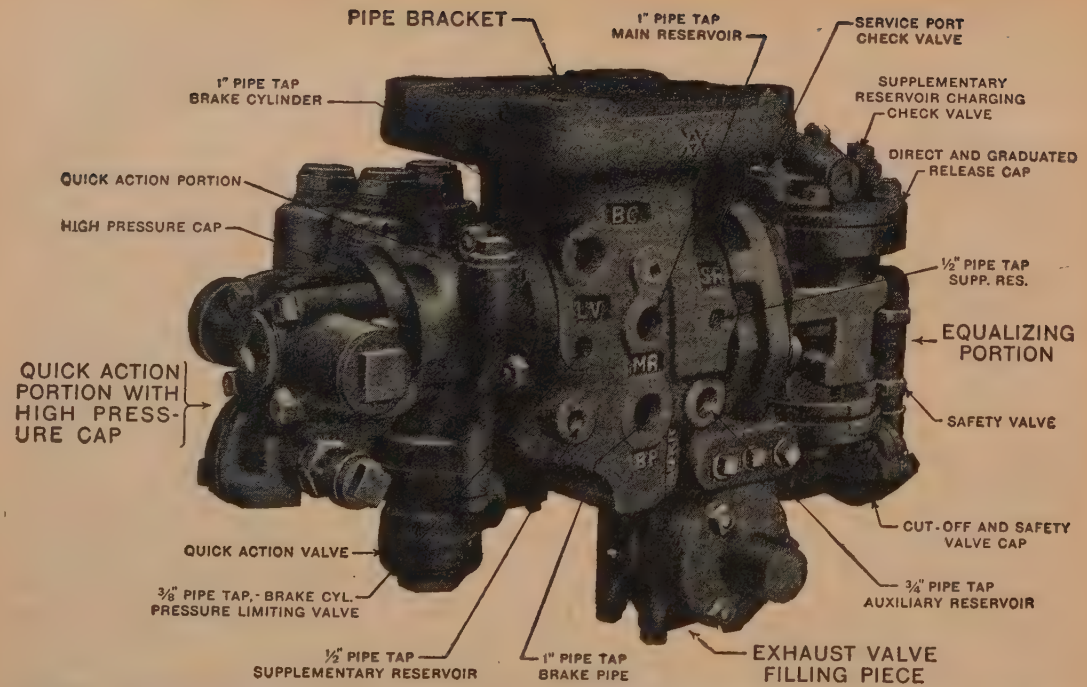


FIG. 6,351.—Westinghouse universal valve showing pipe bracket, equalizing portion, exhaust valve filling piece, quick action portion, etc.

Electrically, the emergency magnets are energized throughout the train resulting in an emergency application. Also in this position the bottom finger of the electrical portion of the brake valve contacts with the steel quadrant thereby grounding and short circuiting the line relays so that in the event of air brake failure the operator is able to reverse and buck the motors.

Universal valve.—The electro-pneumatic triple valve called by Westinghouse a *universal valve* is shown in figs. 6,351 and 6,352, and consists of the following portions.

Three face pipe bracket.—This is designated type C, to which are bolted the quick action, equalizing and electric portions and the exhaust valve filling piece, the latter being inserted between the equalizing portion and the pipe bracket. The bracket is bolted to the underframing of the car, all pipe connections being made permanently to this bracket, so that none need be disturbed in the removal or replacement of any one of the operating portions of the universal valve. This bracket contains two chambers, the quick action chamber and quick action closing chamber.

The equalizing portion.—This is similar in operation to the old style plain triple valve. It is this portion which is directly affected during pneumatic operation by differences in pressure between brake pipe and auxiliary reservoir, and it controls, either directly or indirectly through the medium of the other portions of the universal valve, the desired charging of the reservoirs, and when operating pneumatically, controls the application of the brake in service, and the release of the brakes. This portion has a direct and graduated release cap which may be set either for direct release or graduated release operation as desired.

The quick action portion.—This includes the various parts controlling the quick action and high pressure functions.

The exhaust valve filling piece.—This is inserted between the equalizing portion and the pipe bracket, which interlocks the electric and pneumatic features of the brake on a car so that if either the release or service magnets fail to operate as intended, the pneumatic application and release functions of the brake remain unimpaired.

When operating electrically, it also cuts off the auxiliary from the supplementary reservoir and closes the brake cylinder exhaust passage.

The electric portion.—This comprises the *service, emergency and release magnets and emergency switch.* The service and release magnets with their attached valves control the electric service applications and release of the brakes. The emergency magnet with its valve controls the operation of the emergency parts of the universal valve. The emergency switch closes the emergency magnet circuit during an emergency application.

The emergency switch and piston might be called the connecting link between the pneumatic and electric emergency functions of the equipment. It serves as a circuit closer to start the electric transmission of quick action throughout the train when originating pneumatically.

A magnet valve cut out cap, by means of which the service magnets as a unit may be cut out independent of the emergency magnet and vice versa or all may be cut out as may be necessary, is included in the electric portion.

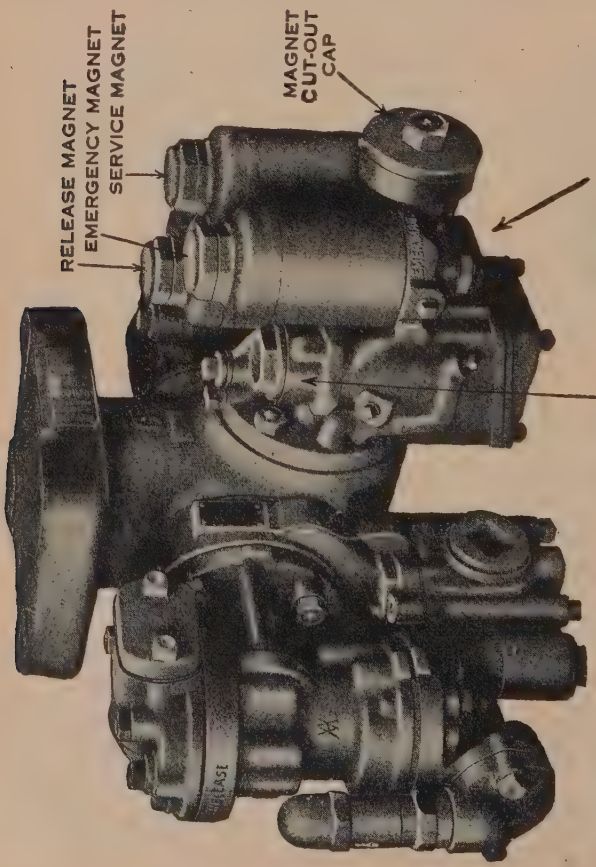


FIG. 6,352.—Westinghouse universal valve showing electric portion.

Hints to Motormen and Conductors.—These instructions will be found helpful in coping with various mishaps which sometimes occur in the operation of trains, fitted with electro-pneumatic brakes.

Cutting out brakes.—It is important not to cut out the brake on any car unless it be impossible to operate it. Small leaks are not sufficient cause for thus reducing the braking force on the train. After cutting out the brake on any car (by closing the cut out cocks in the branches from the main reservoir and brake pipes to the universal valve) release its brakes by opening the auxiliary reservoir and supplementary reservoir drain cocks and leave them open.

Unexpected brake applications.—Such applications may be due to the use of the conductor's valve, the train breaking in two, a bursted hose, or rupture in the piping. In such event the motorman should at once place the brake valve handle in *lap position*, and watch the gauge. If the black pointer fall, it indicates a leak in the brake pipe and if both pointers fall, it indicates that the train is broken in two or a leak in the main reservoir pipe. If this leak be found to be in the brake pipe, after securing the train with the hand brake, place the brake valve in *release position* and carrying handle return along side of train and locate leak.

Conductor's valve.—Should the conductor find it necessary to set the brakes from within any car, the cord or handle of the conductor's valve should be pulled down as far as possible. This valve must be closed, of course, before signalling the motorman to go ahead; otherwise brake pipe pressure will continue to escape and the brakes cannot be released.

Brake pipe rupture.—In event of a brake pipe hose bursting, or if the brake pipe be ruptured, close the cut out cocks in the brake pipe and main reservoir branch pipes to the universal valve and the brake pipe cut out cocks next ahead of and behind the point of rupture, and release the brake on the car thus cut out by bleeding the auxiliary and supplementary reservoirs. If this car be at or near the rear of the train, release the brakes on the rear cars by the nearest brake valve, leave the brake valve in *release* and operate from the head section. Whenever brake pipe cut out cocks have been closed, the train should be operated with caution from the longest section. All brakes will operate electrically except on the car cut out, but if the electric brake circuit fail, the pneumatic brakes can only be controlled to the point where the angle cock is closed.

Main reservoir pipe rupture.—Should a main reservoir pipe or hose burst, close both main reservoir and brake pipe cut out cocks, the cut out

cock in the brake pipe branch pipe to the universal valve, and release the brakes by bleeding the auxiliary and supplementary reservoirs. Cut out the compressor switch and proceed the same as with a burst brake pipe.

Branch pipe rupture.—Should a brake pipe branch pipe break between the universal valve and the cut out cock, close the cut out cock and release the brake on that car by opening and leaving open the auxiliary and supplementary reservoir drain cocks, and proceed as usual. If the break occur between the cut out cock and the brake pipe, it is, in effect, a brake pipe rupture and the instructions given under that heading should be followed. If the main reservoir pipe branch pipe break between the cut out cock and the universal valve, close this cock and proceed as usual. If the main reservoir pipe branch pipe break between the cut out cock and the main reservoir pipe, it is, in effect, a main reservoir pipe rupture, and the instructions given under that heading should be followed. After cutting out the brakes on a car charged with air for any of preceding troubles, before moving train make an emergency application of the brakes, then release brakes and proceed.

Overcharged brake pipe.—Should the brake pipe become temporarily overcharged, thereby preventing a proper release of the brakes, make successive applications of 20 lbs. and release, charging the brake pipe to within 5 lbs. of previous pressure after each release. Further overcharging may be prevented by placing the brake valve in handle off position. To prevent brake creeping on in case brake pipe is leaky, move brake valve handle to *release* momentarily, then back to *handle off position*.

Leaving cab.—Whenever the motorman leaves the cab, as in changing ends, etc., he should make a 20 lb. reduction and moving the handle to *lap*, remove the handle, leaving brakes set.

TEST QUESTIONS

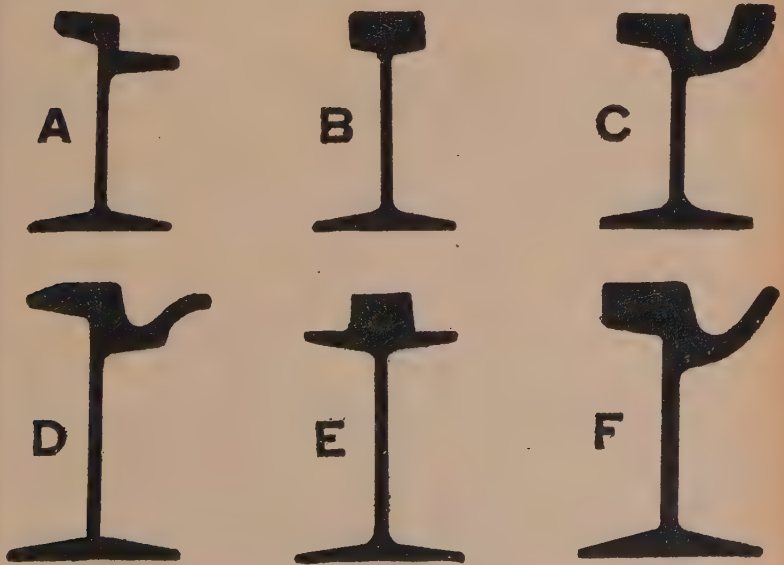
1. *Name the various kinds of air brakes.*
2. *How does the emergency air brake differ from the straight air brake?*
3. *What is the meaning of the word "automatic" as applied to air brakes?*
4. *For what service is the automatic variable release type air brake used?*
5. *What is the feature of the automatic variable release type air brake?*
6. *What is the adaptation of the quick acting automatic air brake?*
7. *How does the quick acting type differ from the variable release type?*
8. *What is the object of the electro-pneumatic type of air brake.*
9. *Describe the straight air brake.*
10. *Give rules for operating a straight air brake.*
11. *Name an objection to the straight air brake.*
12. *How is the objection in the previous question overcome?*
13. *Name the various parts of an emergency straight air brake.*
14. *Describe the operation of an emergency straight air brake.*
15. *What apparatus is necessary to accomplish the automatic application of the brake in case of accidents?*
16. *What are the functions of a triple valve used with the automatic air brake?*

17. *Describe the method of operating the automatic air brake.*
18. *How is the operation of the automatic air brake best explained?*
19. *What is an automatic variable release air brake?*
20. *How does the quick acting automatic air brake differ from the plain automatic brake?*
21. *For what service is the quick acting automatic air brake designed?*
22. *How is a triple valve modified for quick action?*
23. *For what service is the combined automatic and straight air brake designed?*
24. *Name the conditions for which the electro-pneumatic air brake is adapted.*
25. *Upon what does the operation of an electro-pneumatic brake depend?*
26. *Name the parts of the electro-pneumatic brake.*
27. *Give the rules for operating an electro-pneumatic brake.*

CHAPTER 138

Tracks

The distinction between the tracks for steam and electric railroads becomes less pronounced as the traffic conditions under which they operate tend to become similar. Figs. 6,353 to 6,358



FIGS. 6,353 to 6,358.—Various girder rail sections. **A,** plain girder rail; **B,** high tee, or Shanghai rail; **C,** grooved girder rail; **D,** Trilby girder rail; **E,** center bearing girder; **F,** deep flange girder

show some familiar girder rail sections. Ordinary tee rails are to a large extent supplanting the girder and grooved sections in city streets.

Electric roads are extending into country districts over private right of way, permitting the use of steam railroad standards, both for road bed and equipment, so that many of the track structures used for steam roads are equally applicable to electric roads.

There is a small but appreciable mileage of tracks laid in paved streets where the use of standard split switches is not practicable and a double tongue switch or a tongue switch and mate, must be substituted for the former to insure proper provision of flangeways. While girder rail construction is desirable, provided the expense is justified, satisfactory results may be obtained from built up tee rails in places where the nature and depth of the paving permit of their use.

Track work involves in addition to the installation of the rails, such devices as guard rails, switches, frogs, cross overs, etc.

In order to understand clearly the explanations of this chapter, familiarity with the terms commonly used in track work is essential.

Definitions

Closure rail.—The length of rail necessary to connect the heel of switch with the toe of frog, either on the lead or on the lead curve.

Connecting track.—A track which differs from a cross-over in that the tracks between which it lies are either oblique to each other, or if parallel, are more remote than the track centers ordinarily employed.

Crossing.—A structure designed to permit one track to cross another at grade, usually made up of four connected frogs, one for each intersection.

Crossover.—A track made up of two turnouts, with the track between the frogs, so arranged as to form a continuous passage between two nearby and generally parallel tracks.

Double crossover.—A combination of two crossovers in opposite directions which intersect between the parallel tracks; also called scissors crossover.

Frog.—A device for use where two running rails intersect, it has provision of flangeways to permit wheel flanges traveling along either rail to cross the other.

Frog angle.—The angle formed by the intersecting gauge lines of a frog.

Frog number.—One-half the co-tangent of one-half the frog angle, and is the number of units of center line length in which the spread is one unit.

Guard rail.—A rail or other device laid parallel with the running rail opposite a frog to form a flangeway with this rail and hold the wheels of equipment to the proper alignment when passing the point of frog. The guard rail is also placed parallel with the running rail ahead of a split switch so as to form a flangeway with the rail to hold the wheels of equipment in proper alignment when approaching the switch.

Guard rail gauge.—The distance from the gauge line of the frog to the flange side of the guard rail, measured $\frac{5}{8}$ in. below the top of the rail, and is always 4 ft. $6\frac{3}{4}$ in. whatever the track gauge may be.

Half-inch point of frog.—The point where the spread between the gauge lines is $\frac{1}{2}$ in. Its distance in inches from the theoretical point, or the intersection of the gauge lines of the frog, measured toward the heel, is equal to one-half the frog number.

Heel end of frog.—The end farthest from the switch.

Heel length.—The distance between the heel end and the half-inch point of frog measured along the gauge lines.

Heel of switch.—The end opposite the tapered end of switch or point rails.

Heel spread.—The distance between the gauge lines at the heel of the switch, standardized at $6\frac{1}{4}$ in.

Knuckle rails.—Used in slip switches. Rails bent to an obtuse angle equal to the supplement of the angle of the slip switch crossing, against which the two pairs of tapered movable rails bear.

Ladder track.—A diagonal track from which several tracks diverge through separate turnouts.

Latches.—Latches and locks are used to secure the switch against improper movement.

Lead.—In a turnout the length between the actual point of switch and the half-inch point of frog measured along the main track.

Lead curve.—The curve interposed between the heel of switch and toe of frog.

Movable point frogs.—These consist of tapered rails lying against a knuckle rail and so connected that they provide passage on one or the other of the intersecting tracks.

Point of switch.—The tapered end of the switch or point rails.

Rail braces.—Stays used to prevent the rails pushing out or turning over.

Scissors crossover.—See double crossover.

Slip switch.—A combination of a right and a left hand switch in the case of a single slip, and of two right hand and two left hand switches in the case of a double slip, together with the track between them, placed within the limits of the crossing of one track by another and connecting the two intersecting tracks on one or both sides of the crossing, respectively, without the use of separate turnout frogs.

Split switch.—A device consisting of two tapered movable rails, with the necessary fixtures, which is designed to divert rolling stock from one track to another.

Switch angle.—The angle included between the gauge lines of the switch rail and stock rail.

Switch plates.—Used to support the point rails at the proper elevation and to maintain the stock rails in position.

Switch rods.—Braces to hold the switch rails the correct distance apart and to keep them from rising as well as to supply the means for connecting them with the switch stand.

Switch stand.—This provides the means for throwing a switch or movable point crossing, except when they are operated by a power device, as at an interlocking.

Target and lamp.—Used to indicate the position of the switch.

Throw of switch.—The distance through which the switch rails are moved sidewise, measured along the center line of the switch rod nearest the

vertex, to bring either point against the stock rail. This distance has been standardized at 4¾ in.

Toe end of frog.—The end nearest the switch when the frog is in track.

Toe length.—The distance between the toe and the half-inch point of frog, measured along the gauge lines.

Toe spread.—The distance between the gauge lines at the toe end of the frog.

Turnout.—The connection of one track with another, consisting of a

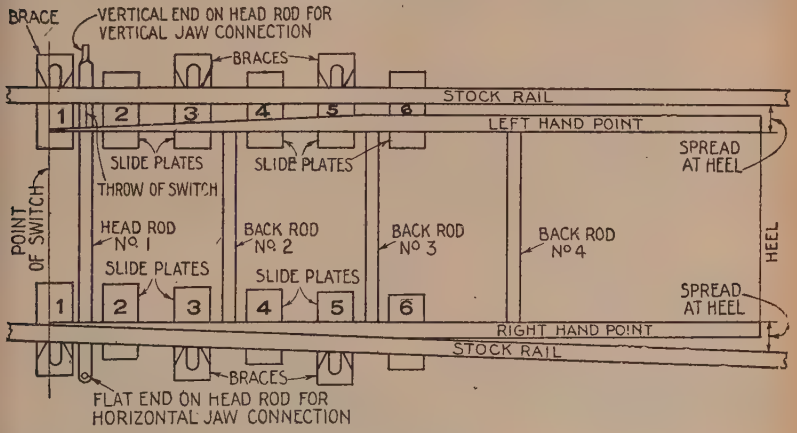


Fig. 6,359.—Diagram of split switch with names of parts.

switch, frog, two guard rails (except where the frog is self guarded), and the various connecting and operating parts.

Vertex.—This is the point where the gauge line of the switch rail, if produced, would intersect the gauge line of the stock rail, and is the point where the stock rail bend is introduced. Also called the theoretical point of switch.

Switches.—A switch is *a device for diverting rolling stock from one track to another*. There are several kinds of switch, classified as:

1. Split;
2. Three throw;
3. Derailing.

The split switch is the one mostly used. It consists essentially of *two switch or point rails, known as the right hand and left hand*

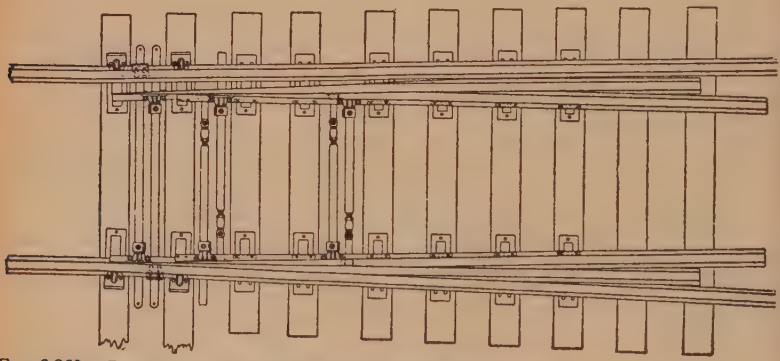


FIG. 6,360.—Racor three throw split switch with adjustable rods.

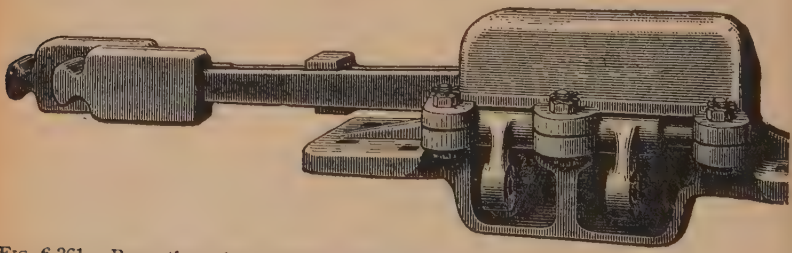


FIG. 6,361.—Racor three throw ground throw switch stand.

points; one or more rods to hold the switch rails in correct relation with each other and to keep them from rising; gauge and switch plates to elevate the switch rails to the required height with respect to the stock rails and to maintain the stock rails rigidly in position in conjunction with plain or adjustable braces; and auxiliary

devices for securing, adjusting, insulating or protecting the several parts of the structure.

Fig. 6,359 illustrates a *split switch* giving names of parts. Switch rods are necessary to maintain the switch points the correct distance apart at the point end of the switch, as is done by the heel blocks or shoulder tie plates at the heel of the switch.

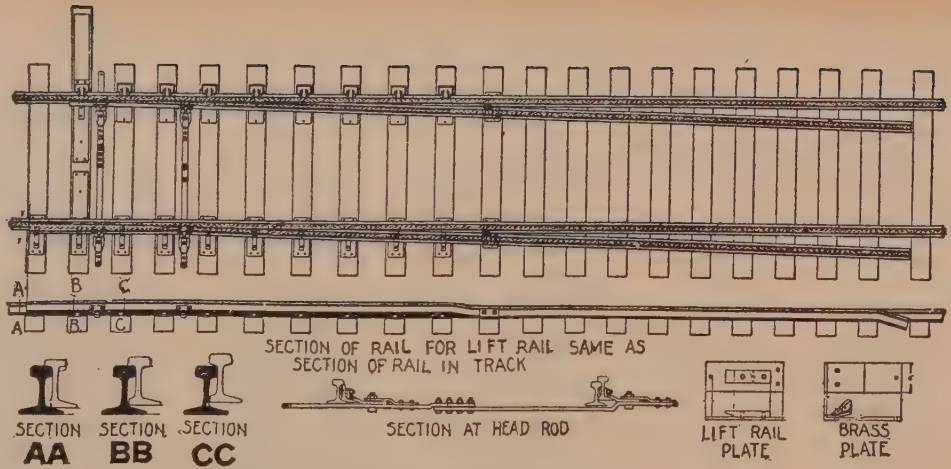
A *three throw switch* is used where two turnouts from the same side or from opposite sides of a parent track have their origin at a common point, so that one switch stand can operate the two switches.

The two switch points which heel on the middle one of the three tracks have their points approximately opposite each other, although connected to different operating rods, while the points which deflect the traffic to one or the other of the outside tracks are staggered with these at the point end and usually also at the heel end, approximately the distance between centers of ties. The respective staggered points are connected through special clips which permit of close engagement of the two switch rails when set for either outside track, so that the inner point backs rigidly against the outer point which in turn backs upon the stock rail. Fig. 6,360 illustrates a three throw split switch with adjustable rods, and fig. 6,361 the type of stand used for this switch.

Although *a derailing switch* is not favored in the main track, and a properly designed deflecting track is given preference, one or the other of these devices is a necessity for checking runaway trains on heavy grades.

The lifting derail, which provides for an unbroken main line when set for a clear track, is effective either as a switch derail or a switch connection for a deflecting track. It is made up of a standard switch point, which engages the wheels on one side to deflect the car, while a specially designed section of rail lifts the opposite wheels and permits their flanges to pass over and off the running rail upon the ties or into a parallel deflecting track.

Frogs.—A frog is *a device which is introduced at the intersection*



FIGS. 6,362 to 6,369.—Racor lifting derail with overlapping one piece lifting rail.

of two running rails to permit the flanges of wheels moving along one of them to pass across the other.

The object of a frog is to support the wheels over the missing tread surface between the throat and half-inch point, and provide flangeways for aligning the wheels when passing over the point so that they will be afforded the maximum of bearing area.

Frogs are classified as:

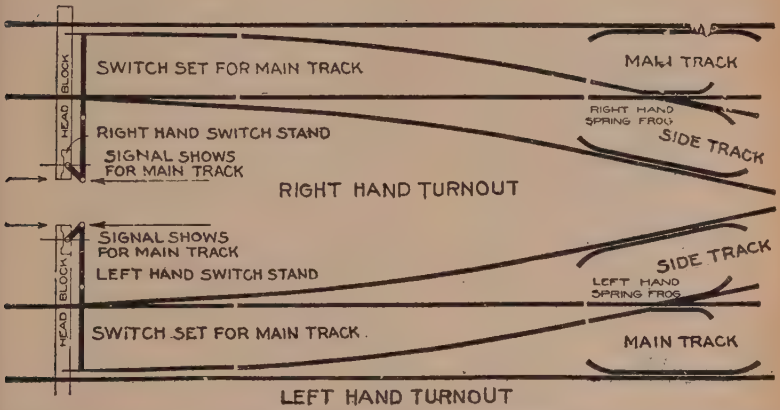
1. Rigid;

2. Spring rail;
3. Sliding.

Each type may be constructed in various ways depending on service desired and conditions under which used.

Frogs may be divided into two principal groups:

1. Turn out;
2. Crossing.



FIGS. 6,370 and 6,371.—Diagrams of right and left hand turn outs, right and left hand spring frogs and switch stands. Spring rail frogs must be used right hand or left hand for right or left hand turnouts as shown. Switch stands of the single throw type, without means for changing position of signal staff should be used right and left hand. Some types of stand are interchangeable for right or left hand turnouts.

These, however, overlap as when standard turnout frogs form the end frogs of a crossing, or a double pointed frog is required for a turnout from three rail combined standard and narrow gauge track.

Standard turnout frogs are generally in two principal classes:

Rigid frogs, which have no movable parts;

Movable wing frogs, in which one or both of the wings move outward to provide flangeways.

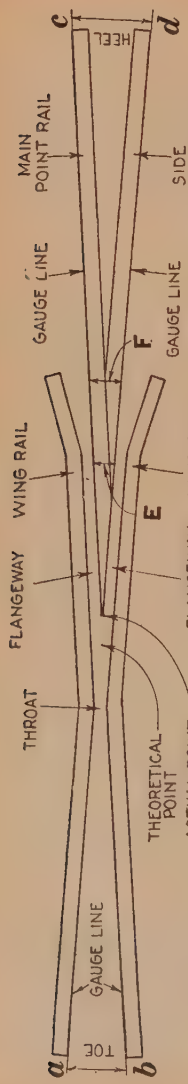


FIG. 6,372.—Parts of frog and simple rules for measuring angle. The angle or number of a frog can be obtained by dividing the total length in inches by the sum of *ab* and *cd* in inches. Another and simpler method: Mark point of frog where it is 2 inches wide at E. Mark also where 3 inches wide as at F. The distance between these two lines in inches is frog number.

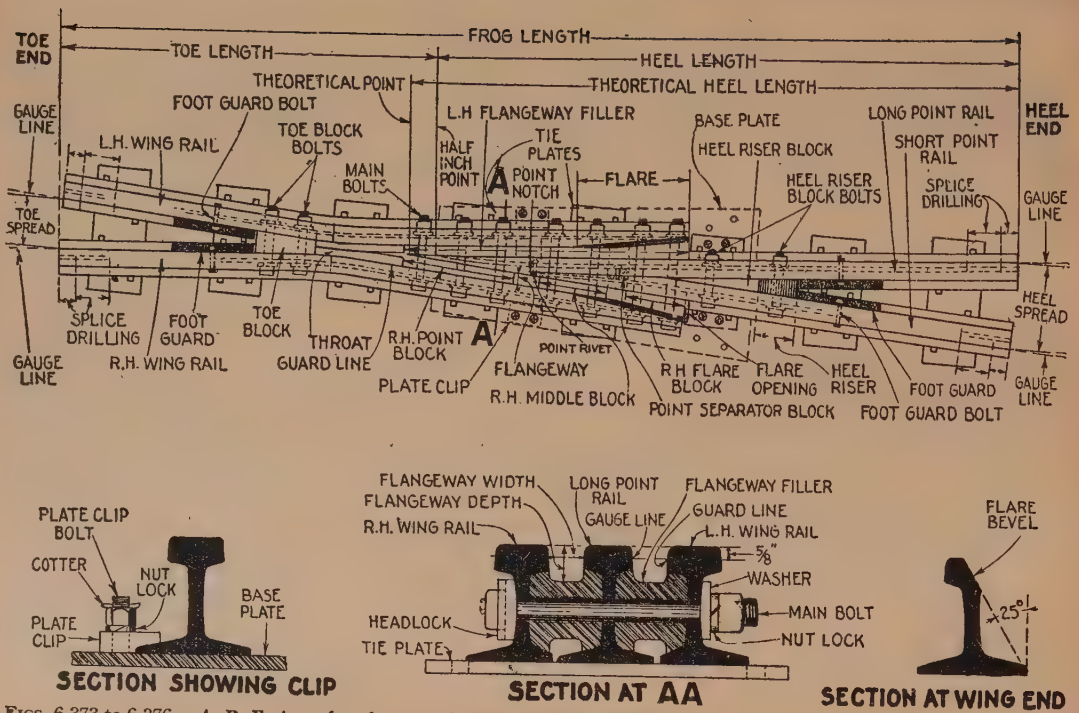
The rigid frogs include the bolted or clamped patterns, the manganese railbound, manganese solid and self-guarded frogs. The movable wing frogs include the spring rail frogs, these being right hand when the wing moves to the right, looking from the toe toward the point of frog, or left hand when the reverse is the case; and double spring rail frogs, in which the wing rails open both to the right and left. The rigid type of frog is commonly used where the traffic is approximately equal on both tracks, although rigid frogs of manganese railbound construction are extensively used at interlocking layouts regardless of the relative amounts of traffic.

The lighter types of rigid bolted and clamp frogs are more generally confined to yards and industrial tracks.

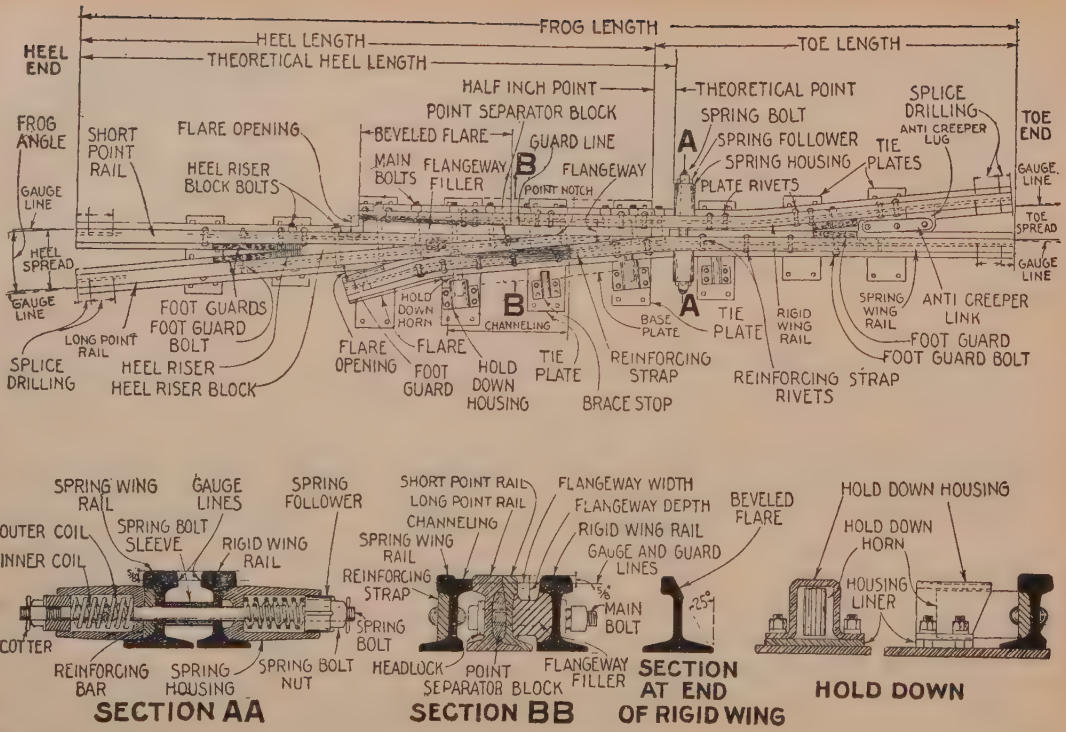
The spring rail frog is given preference over the rigid bolted frogs for main track turnouts other than at interlockings, although manganese railbound frogs are also much used in such places. The spring rail frog provides a practically continuous rail for the main track and is considered by many to afford easier riding and an increased life of the structure in the track.

The double spring rail frog is employed primarily where it is necessary to take care of narrow wheel treads occurring in a mixed traffic, as where operation is by both electric and steam trains.

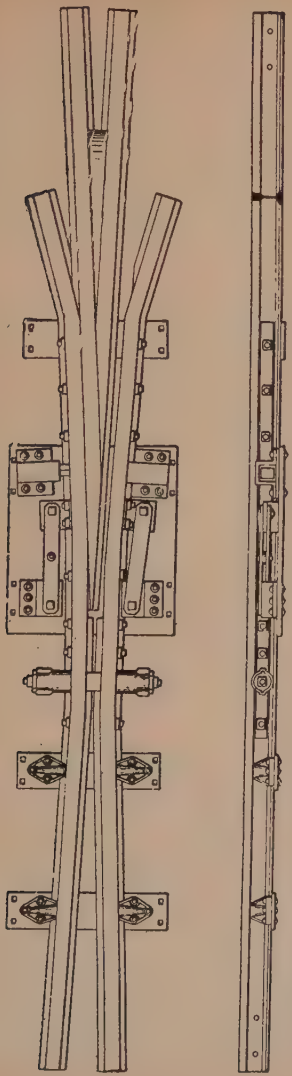
The parts of a frog and simple rules for measuring angle are



FIGS. 6,373 to 6,376.—*A. R. E. A.* preferred names of parts for bolted rigid frogs.



FIGS. 6,377 to 6,382.—*A. R. E. A.* preferred names of parts for spring rail frogs.



Figs. 6,383 and 6,384.—St. Louis sliding wing rail frog.

given in fig. 6,372. Figs. 6,373 to 6,376 show the construction of a rigid frog with names of parts.

Spring rail frogs differ from the rigid type in that they have *one or both of the wing rails held close to the point rails by means of a spring*, thus avoiding the flangeway opening and permitting the wheels to ride over the structure without the jar or pound that is so destructive to the rigid frog.

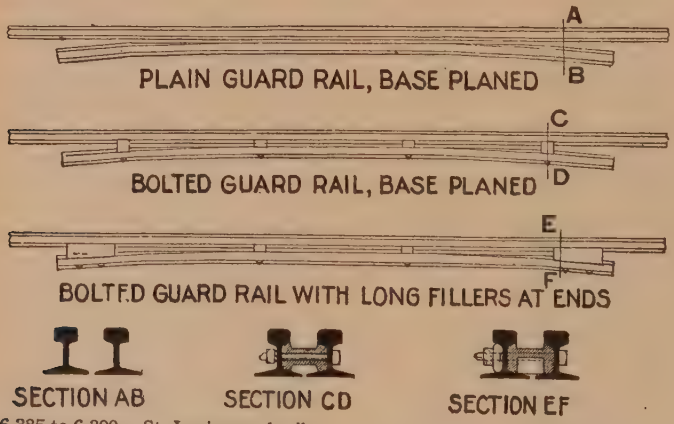
This also eliminates vibration to the rolling stock, on which account the spring frog has been generally used on main line turnouts where movement into sidings is infrequent. Figs. 6,377 to 6,382 show construction of a spring rail frog.

The action of the sliding rail frog is due to the car wheels in passing over the frog, the wheel flanges automatically moving the wing rails in passing over. Figs. 6,383 and 6,384 show the construction.

Guard Rails.—These are of three general classes:

1. Turn out;
2. Curve;
3. Bridge.

The turnout guard rail is designed to prevent the wheel flanges striking the points of frogs and switches, except where the frogs are self-guarded or the switches protected by a manganese steel flange.



FIGS. 6,385 to 6,390.—St. Louis guard rails.

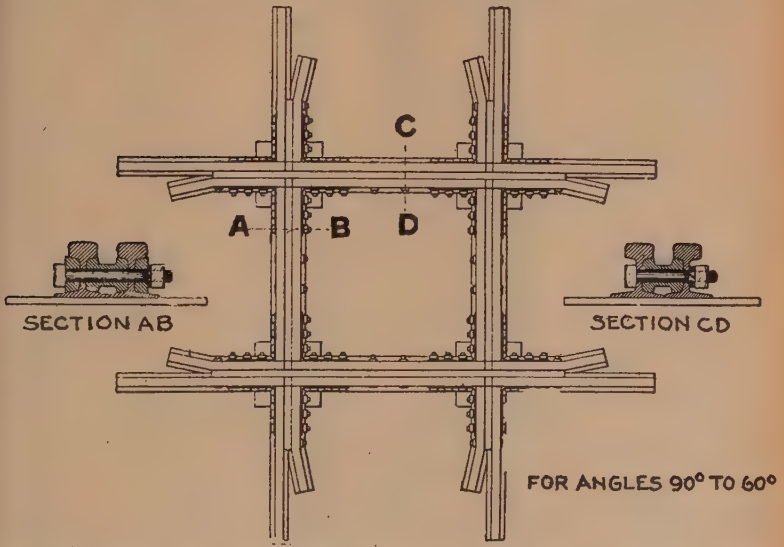
The curve guard rail is installed on the sharper curves to avoid derailment and to reduce side wear of rail and flanges. The bridge guard rail is intended to keep derailed wheels from running off the ties.

Guard rails are discussed herein principally as regards the turnout guard rail, although incidental mention is made of the curve guard rail, since its position in the track is based on somewhat the same mathematical principles and it employs similar auxiliary equipment.

While the ends of both turnout and curve guard rails are frequently cut square they may alternately be depressed or beveled as a provision against dragging parts of cars catching upon them. As a further precaution the ends of the guard rail are made to rest on a tie wherever practicable. Both types of guard rail also require flares at their ends, to align the wheels into their proper course without shock. The required width of flare opening is

usually maintained by end blocks, which also serve as foot guards. All types of guard rails require an adequate means of bracing them against the side thrust of traffic.

Crossings.—The structure used at the intersection of two tracks, adapted for the passage of flanged wheels is termed a



FIGS. 6,391 to 6,393.—St. Louis crossing, two rail both tracks. Fig. 6,391, section AB; fig. 6,393, section CD.

crossing. Crossings are constructed to meet the conditions of service to which they are subjected. For those infrequently used or for light equipment, it is unnecessary to provide the substantial types that frequent trains, high speeds and heavy rolling stock would call for.

A crossing consists of *four frogs, one for each rail intersection, connected together and provided with arms at the four corners for attachment of the main rails.*

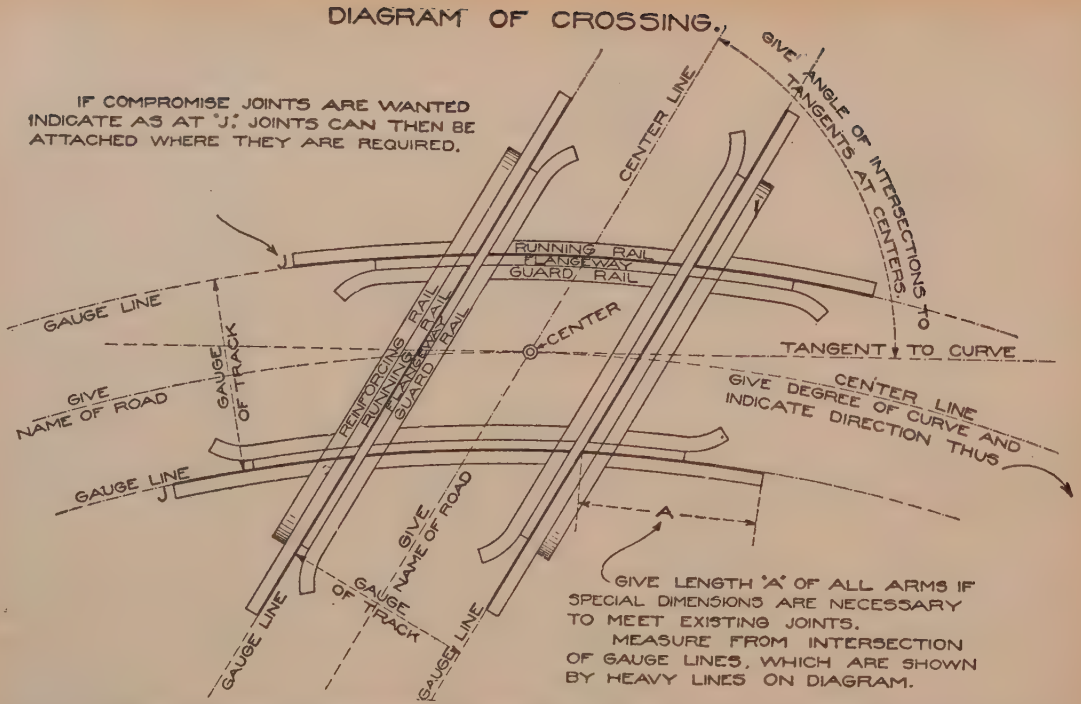
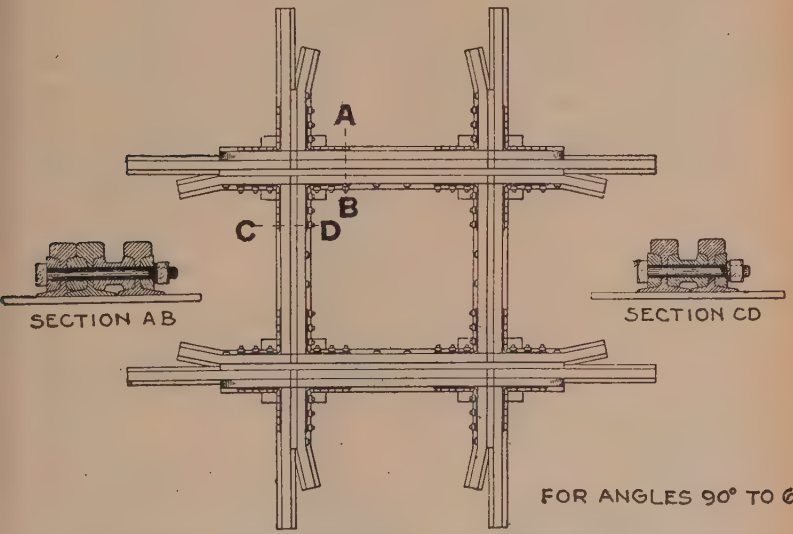


FIG. 6,394.—Diagram of crossing. ***In specifying,*** give angle of crossing preferably at the intersection of center lines though this may be taken at gauge line intersections if more convenient. If either track be curved, give the angle at intersection of tangents to curve and radius of degree of curvature. In the case of curved crossings, sketch must also indicate direction of curve.

The necessary protection of the points of the crossing, as well as the desirable provision of continuous flangeways, requires the addition of inner guard rails, extending also to the required distance beyond the intersections, except that in the simpler design for small angles the acute angle intersections may be protected by ordinary guard rails.

A third rail, known as easer rail or simply easer, is usually provided outside the running rails for reinforcement and to supply a bearing for the overhanging portion of hollowed out treads of wheels. The easer rails may be



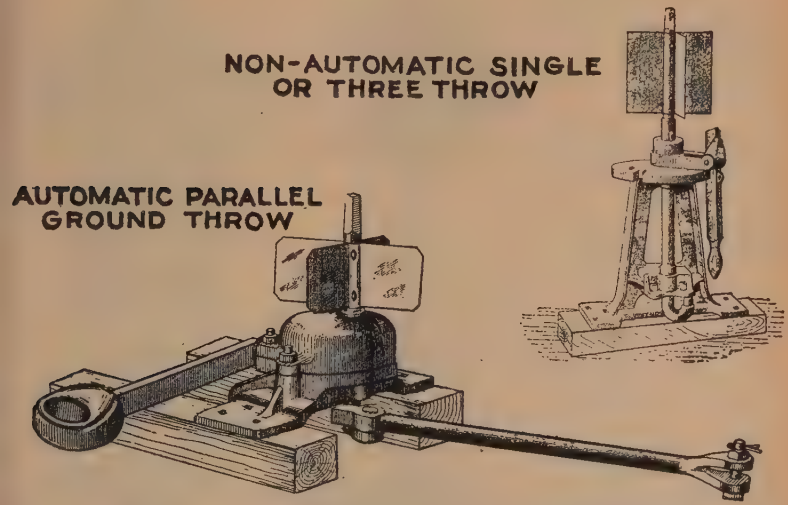
FIGS. 6,395 to 6,397.—St. Louis crossing, three rail one track. Fig. 6,395, section AB; fig. 6,397, section CD.

continuous throughout the crossing, or as is frequently the case for the smaller angles, of a length only sufficient to protect the immediate intersections.

When the angle at which the tracks intersect is other than 90° the two frogs at the acute angle intersections are called end frogs, and at the obtuse angle intersections, center frogs.

FIGS. 6,398 to 6,401.—*A. R. E. A.* tie layouts for railroad crossings.

End frogs as well as center frogs are double pointed except in the crossings of single rail design, sometimes used for angles below 25° in which the end frogs are standard turnout frogs protected by standard guard rails. The additional point in the end frogs is formed by the intersection of the guard rails of the crossing, while in the center frogs each of the two points is formed by the intersection of a running rail and a guard rail. The general layout of a crossing is shown in fig. 6,394.



FIGS. 6,402 and 6,403.—St. Louis switch stands. Fig. 6,402, non-automatic single or three throw, supported on one tie, safety bottom cap prevents removal of connecting rod, except by removal of stand or switch head rod; fig. 6,403, automatic parallel ground throw yard stand with movement of lever parallel with track. When used without latch the operation of this stand is automatic; that is, the lever will throw over in case switch is run through on a trailing movement. With latches, stand becomes positive and may be locked in either position.

Figs. 6,391 to 6,397 illustrate crossing construction and figs. 6,398 to 6,401 arrangement of cross ties at crossings.

Switch Stands.—The modern switch stand consists essentially of a base, a spindle and a throwing lever. The latter is moved through a part of a circle, either horizontally to impart directly

a rotary motion to the spindle, or vertically, when some form of crank arm motion, or a mechanism of cams or beveled gears, is necessary to effect the rotation. A crank on the foot of the spindle serves to change the circular motion of the spindle into rectilinear motion to effect the throwing of the switch.

The manner in which the stands are thrown separates them into the two general classes:

1. Horizontal throw;
2. Vertical or ground throw.

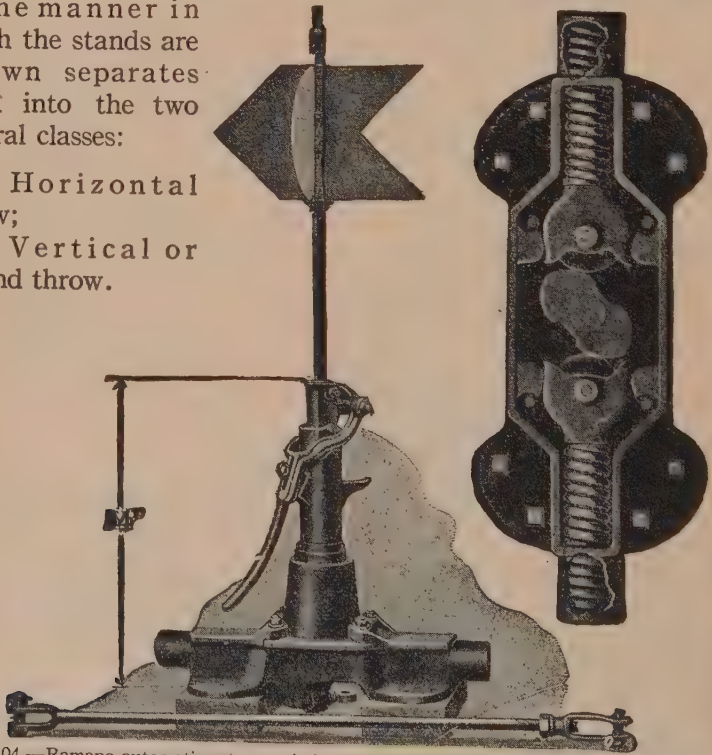


FIG. 6,404.—Ramapo automatic return switch stand designed principally for passing sidings on electric traction lines where it is desired that the switch after being run through shall be returned automatically to its original position. It may also be used similarly at special locations and in yards. The design of the stands is the same as in the automatic safety stands, except that the star piece is replaced by a lever arm with four curved faces. Two diametrically opposite faces are in contact with the roller plungers and compress the springs, which upon passage of the wheels rotate the spindle back to its normal position.

FIG. 6,405.—Ramapo automatic return switch stand, section of base.

Switch stands are further classified as:

1. Non-automatic (rigid throw);
2. Automatic;

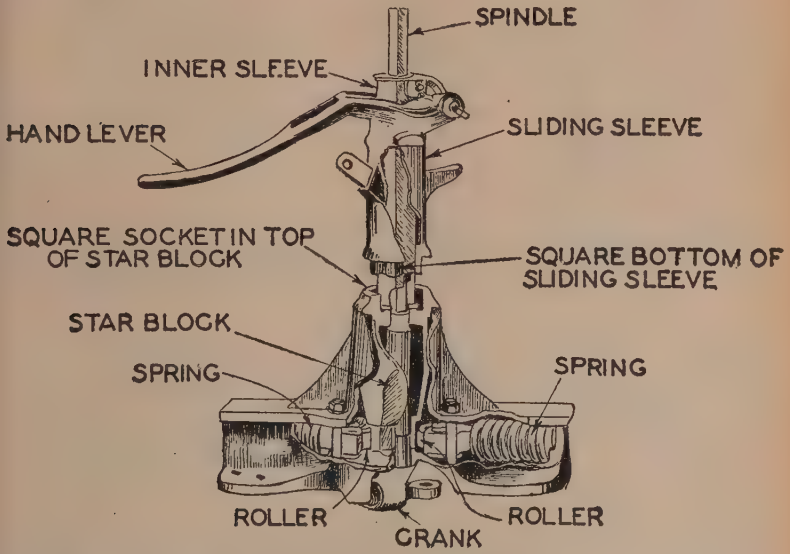
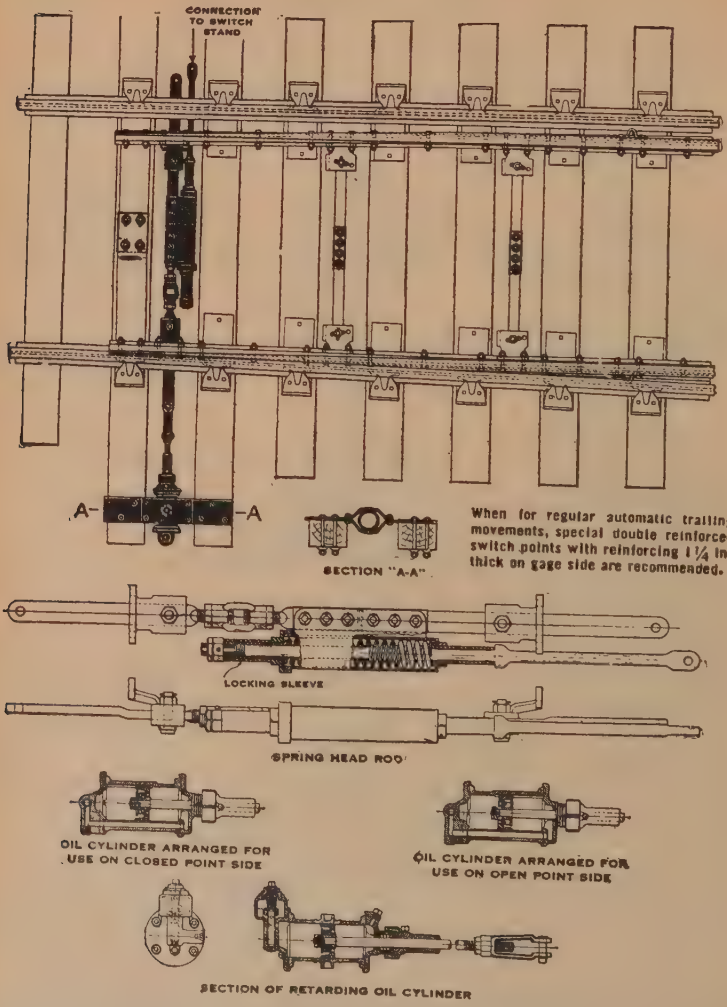


FIG. 6,406.—Ramapo automatic safety switch stand in hand operation. ***In hand operation,*** the hand lever is lifted, this action raising the sliding sleeve so as to disengage it from the star block, when the spindle, which is circular where it passes through the star block, will turn freely therein. When the switch is thrown the hand lever cannot be lowered and the sliding sleeve restored to engagement with the star block until the full movement of the switch has been completed, thus making operation by hand entirely positive. When engagement of the clutch has taken place the spindle is rigidly connected with the star block and is again in position for automatic operation or the switch stand may be operated by hand as before.

NOTE.—***Ramapo automatic safety switch stand.*** Explanation of automatic operation. ***In operation,*** when a switch is run through, the first pair of wheels forces the switch over and rotates the spindle connected to it through its crank and the switch connecting rod. The spindle, being rigidly connected with the star block through the clutch between it and the outer sleeve, also is rotated. The bottom of the star block is provided with a star member which is always in contact with roller plungers at the free ends of spiral springs, so that it can only rotate against the compression of the springs. When the star points pass the center line of the spring members the pressure of the springs forces the switch point against the opposite rail. Innumerable tests have shown that it is impossible for the switch points to remain partly open. The stand is left locked in either position ready for hand or automatic operation.



FIGS. 6,407 to 6,414.—Plan and sectional views of Racor retarding dash pot as installed on a spring switch connecting rod.

3. Automatic safety.

Fig. 6,402 represents a non-automatic stand and fig. 6,403 an automatic stand.

The automatic stand is simply a rigid throw stand with the means of automatic operation added.

The basic principles in the design of the automatic safety type are *positive throw for hand operation and automatic throw, with minimum friction and static resistance, when a switch, set wrong, is run through.*

The switch stand operates automatically whether the stand be locked or not; and since the spindle is rotated fully the target always indicates correctly the position of the switch points. These features not only contribute to the safety of operation, but insure longer life of the automatic stand, while avoiding damage to the switch points and their connecting parts. Fig. 6,406 illustrates the automatic safety type switch stand.

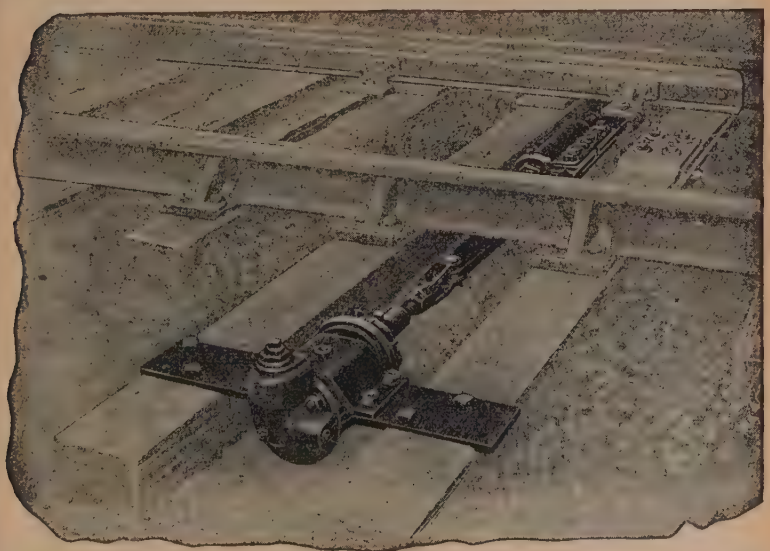


FIG. 6,415.—Racor retarding dash pot for use on spring switches. ***This device,*** working in non-freezing oil, retards the closing of switch points so that they will not snap shut between successive pairs of wheels when trailing through. Makes spring switches practical for steam roads, and is especially useful at passing sidings on electric railways. Saves wear and tear on switch points.

TEST QUESTIONS

1. *How do electric railway tracks differ from steam railway tracks?*
2. *Of what does track work consist?*
3. *Give definitions of the various terms used in track work.*
4. *What is a switch?*
5. *Name the several classes of switch.*
6. *Describe the various classes of switch.*
7. *What is a frog?*
8. *Name the various classes of frog.*
9. *Into what two principal groups are frogs divided?*
10. *How do spring rail frogs differ from rigid frogs?*
11. *What is the purpose of a spring rail frog?*
12. *To what is the action of the sliding rail frog due?*
13. *Name three classes of guard rail.*
14. *What is the object of a turn out guard rail?*
15. *Define a crossing.*
16. *Of what does a crossing consist?*
17. *What is the object of the third rail or easer?*
18. *Describe a switch stand.*
19. *Name two classes of switch stand.*
20. *How are switch stands further classified?*
21. *Describe a non-automatic (rigid) throw stand.*
22. *How does an automatic stand operate?*
23. *What are the basic principles and design of the automatic safety stand?*

CHAPTER 139

Rail Bonding

Since the rails of an electric railway are used as the return portion of the circuit it must be evident that the joints between

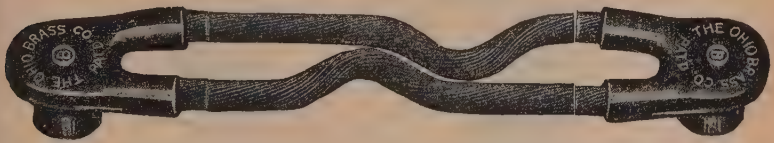


FIG. 6,416.—Ohio compressed terminal rail bond intended for installing on web of rail under splice bar. Can be used singly to span one or more bolts or can be combined for double or quadruple bonding. This is a balanced bond, the two cables being of the same size.

FIGS. 6,417 and 6,418.—Ohio steel armored terminal rail bond for application by gas weld process and view of joint showing bonds welded. Strands are held in ⅛ in. steel terminals. Copper sleeve which distributes and damps vibration, protects the strands where they are held in the terminals. Especially suitable for rail joints where heavily ribbed splice plates are used. Applied by gas weld process which fuses ends of strands into the weld. Welding rod provides the metal for building up the terminal and contains the flux needed for the welding operation. About 20 lbs. of wire will be required for each 100 bonds.

the rails will offer more or less resistance especially because of corroded fish plates.

As rail lengths of 30 or 60 feet are used, there will be 88 to 176 joints per mile, and the resistance of these joints being in series the total resistance per mile of track will be considerable. In order to overcome this, adjacent rails are "bonded," that is joined by stranded copper bonds.

FIG. 6,419.—Ohio armored terminal rail bond adapted to steel metallic arc process. Can be used on rail of 50 lbs. per yard or heavier. Can be applied with any electric arc welding machine. Copper strands are welded to the heavy steel of the terminal. The wires are protected from welding heat by the steel armor. Copper sleeve which distributes and dampens vibration and adds to life of bond, surrounds the wire at the terminal. Operator welds steel to steel with steel. Terminal slopes slightly away from rail. In application there is plenty of room to weld in the angle where it does the most good. When completed the terminal is beveled from the rail. This reduces possibility of injury from car wheels, etc. Terminals are 2 ins. long. Soft steel welding rod is used. About 25 lbs. of rod will be required for each 100 bonds.

Ques. What are bonds?

Ans. Copper straps with terminals for carrying the current around the track joints.

Ques. How are they fastened?

Ans. By drilling holes in the rails and compressing the ends, or terminals, of these copper straps in them.

There are several classes of rail bonds, as:

1. Compressed terminal;
2. Welded terminal.

These types are shown in figs. 6,416 to 6,419.

The compressed terminal has $\frac{5}{8}$ to 1 in. cylindrical heads which are forced into holes drilled in the abutting rails. The holes are drilled by a type

FIG. 6,420.—Moore track drill, for drilling holes in track rails, for bonds or splice plates. It is operated by worm gears and feeds the drill automatically; the advance of the drill being 1 in. for every 50 to 650 revolutions depending on the adjustment and the softness or hardness of the rail.

drill such as shown in fig. 6,420 and the terminal heads of the bond forced into the drilled holes by means of a clamp shown in fig. 6,421.

Various methods of welding are used, such as:

1. Gas;

2. Arc;
3. Cast;
4. Thermit.

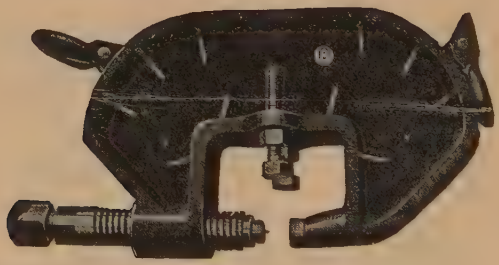
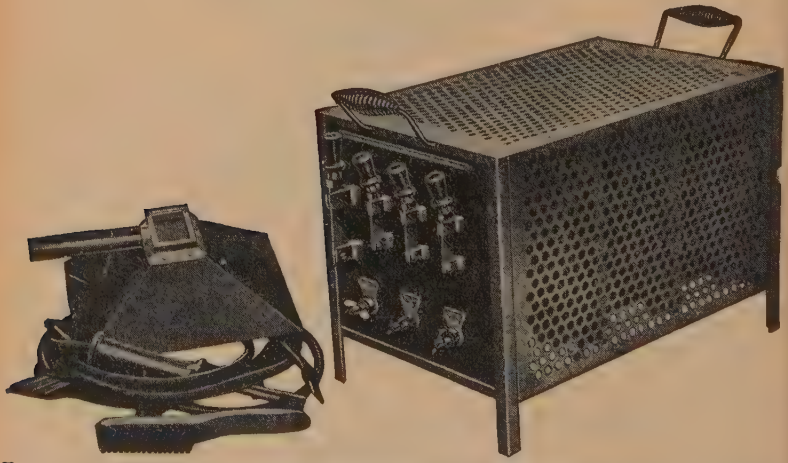


FIG. 6,421.—Ohio rail bond compresser for tee and girder rails.



FIGS. 6,422 and 6,423.—Ohio electric arc welding machine designed for portable *d.c.* railway welding service. The resistance consists of individual units, so designed as to afford support and protection to the coils. The output is adjustable in 30 ampere steps, from 30 to 120 amperes.

The electric arc is used very extensively for welding joints and has resulted in the development of rail bonds which can be applied with the electric arc in one form or another. One form of portable electric arc welding machine is shown in figs. 6,422 and 6,423.

Electric rail bond testing.—One of the best methods of finding the resistance of a bonded joint is to use two milli-volt meters

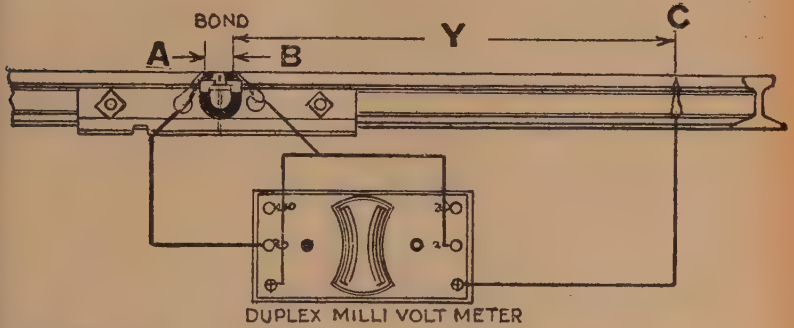


FIG. 6,424.—Diagram illustrating electrical rail bond testing.

FIG. 6,425.—Ohio steel terminal rail bond adapted to copper metallic arc process. This bond is welded to the ball of the rail by electric arc using copper alloy electrode. Steel terminals catch and support the electrode metal and offer mechanical support for the copper cable. Electrode metal forms a fused connection of copper alloy of ample contact area between rail head, steel terminal and the copper strands, mechanically and electrically uniting each to the other. Copper sleeve which distributes and dampens vibration and adds to life of bond, surrounds the wire at the terminal. Special Titon copper alloy welding rod is used. About 25 lbs of rod will be required for each 100 bonds.

and determine the number of feet of rail equivalent to the bonded joint. A duplex milli-volt meter is preferable to two separate instruments and should be connected as shown in fig. 6,424.

There must be sufficient current flowing in the rail to give a fair deflection on the instruments. Contacts A and B, should be placed on the rail head directly over the bond terminals. The contact C, should be moved along the rail until the two needles give the same reading. The drop along the joint is now equal to the drop along Y, feet of rail. As the current is the same in both sections the resistance of the bonded joint AB, equals the resistance of Y, feet of rail. The resistance of rail per foot is given in fig. 6,426.

The added resistance of the bonded joint is therefore equal to Y-AB feet of rail. Where the current flowing in the rail is not great enough to give good deflections on the milli-volt meter, it is customary to operate a line car close to the tester to produce the current flow.

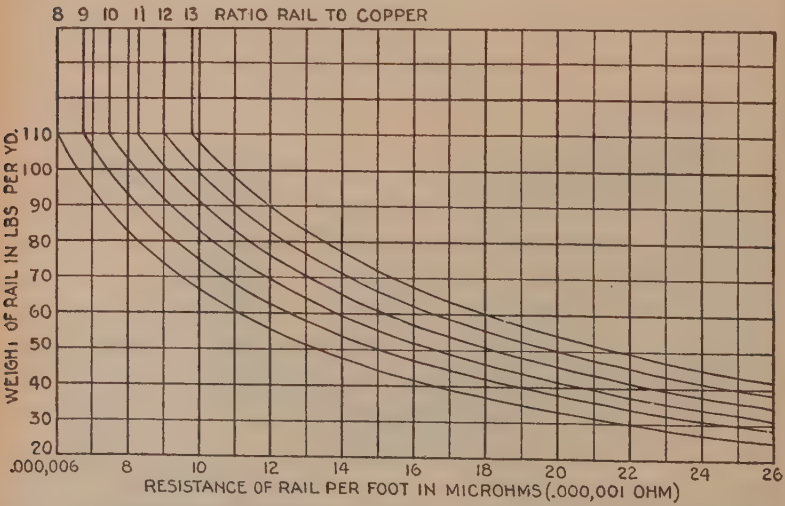


FIG. 6,426.—Chart showing resistance of steel rails; that is the resistance of 1 ft. length of rail in microhms (.000,001 ohm) for different weights of rail and ratios of rail to copper. ***Example.***—What is the resistance per foot of a 70 lb. per yard rail for a ratio of 11 (rail to copper). Follow the horizontal line through 70, at the left, to the right until it intersects the curve marked 11, then follow the vertical line through the intersection downward and read .000,013 ohm per ft.

On alternating current systems, an independent direct current, furnished by a portable dynamo or storage battery, should be passed through the joint and section of rail Y, during the test.

It is highly important to know how much resistance is added to the joint in feet of rail equivalent when the bonding is in good condition.

The old rule that a joint should test three feet of rail or less has no significance and in many cases is entirely wrong.

Fig. 6,427 is a chart which gives the added resistance expressed in equivalent length of rail equal to the bonded joint for various capacities and lengths of bonds and weights of rail when the bond is in the best condition.

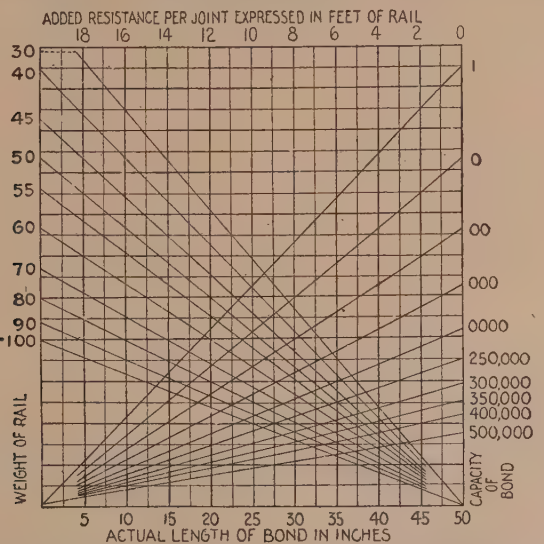


FIG. 6,427.—Chart showing bond resistance. The actual unformed length of the bond, the capacity of the bond and the weight of the rail per yard, must be known. Follow the vertical line through the actual length of the bond (shown at the bottom) until it intersects the diagonal representing the capacity of the bond (shown at the right). Follow the horizontal line through this intersection until it cuts the diagonal representing the weight of rail (shown at the left). Follow the vertical line through this point upward and read the added resistance per joint expressed in feet of rail (shown at top). This chart shows the standard for a given bonded joint with which its actual condition may be compared.

TEST QUESTIONS

1. *Define the term rail bonding.*
2. *Why is rail bonding necessary?*
3. *How are bonds fastened?*
4. *Describe an armored terminal rail bond.*
5. *How does a compressed terminal bond differ from a welded terminal bond?*
6. *Name the various methods of welding.*
7. *Describe the best method of testing rail bonds.*

CHAPTER 140

Subway and Tube Lighting

Lighting of subways differs in some respects from ordinary lighting. The line being underground or under rivers, the lights must be kept burning all the time. Consequently extraordinary precautions must be taken against failure. Emergency sources are arranged to act when the main source fails.

Ques. Does the main source depend on the operating source?

Ans. No. Power off the third rail or trains stopped, must in no way affect the lights.

Ques. Why is this important?

Ans. Should there be a tie up and passengers have to walk through the tunnel they will not have to grope in the dark.

Ques. Mention some typical methods of subway lighting?

Ans. 1. Direct lighting feeders from power houses or substations of the traction company or of another traction company; 2, direct lighting feeders from power houses or sub-stations of electric light companies; 3, connections from both with interchange switches; 4, connections from third rails with interchange switches; 5, connections of separate groups of lights from separate sections of third rails or separate sources.

Ques. How may these be arranged?

Ans. In any combination or group of combinations.

Ques. Describe a typical modern method.

Ans. High tension, 11,000 volt cables run from the traction company's power houses or sub-stations to the subway stations.

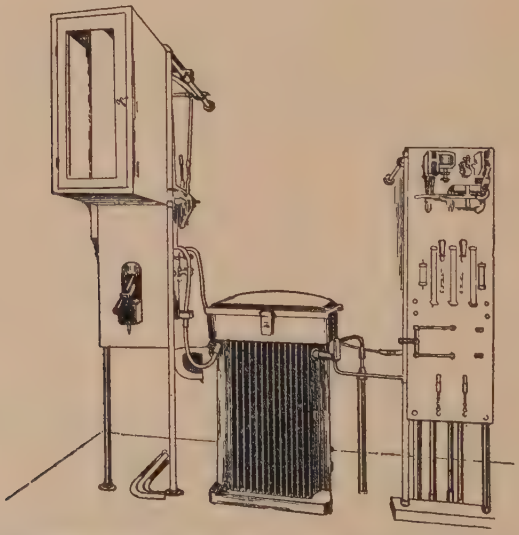
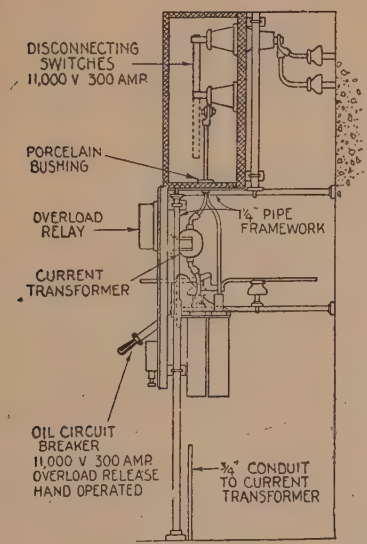


FIG. 6,428.—Transformer room of subway station. The room housing the apparatus for lighting the subway stations and tunnels contains the following: 1, high tension switches in the cabinet at the top of the high tension board; 2, transformer for reducing the 11,000 volts to 600 volts; 3, low tension switchboard for distribution.

NOTE.—Lighting cables for subways. Three conductor, 11,000 volt cables, paper insulated, lead covered, for furnishing the power for lighting the subways. These terminate in transformer rooms located at each subway station *and through switches* and panel boards furnish the power to the various sections. The current is transformed from 11,000 volts to 600 volts, and five lamps burn in series

A transformer room is located at the end of each station platform. The current at 11,000 volts is transformed there to 600 volts and sent along the lines for lighting the stations and tunnels, as shown in figs. 6,431 and 6,432.

Ques. What apparatus is contained in the transformer room?



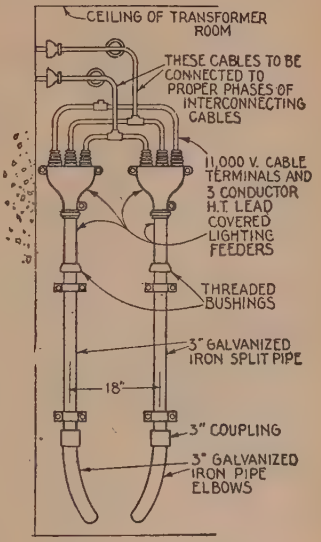


FIG. 6,429.—Subway lighting equipment. Side view of high tension switchboard showing cable connections to high tension knife switches, current transformer, oil circuit breaker, etc., and the mounting of the switchboard as related to the wall.

FIG. 6,430.—Subway lighting cables. The connections of the three conductors of high tension lighting cables and the taps taken off for transformer connection, showing method of fastening cables to wall.

Ans. A high tension switchboard, a transformer and a low tension switchboard.

Ques. What does the high tension switchboard consist of?

Ans. A cabinet containing two single pole 11,000 volt knife switches, to which the main cables connect, a panelboard and a current transformer, relay and oil circuit breaker for automatically opening the circuit in the event of a short circuit, ground or for repair or test.

Ques. What does the transformer do?

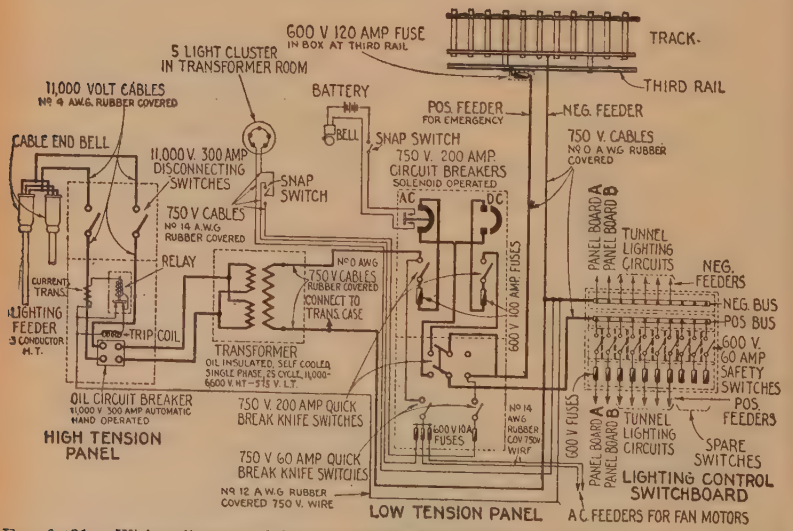


FIG. 6,431.—Wiring diagram of lighting equipment of subways. The current is transmitted from the power house or sub-station at 11,000 volts through high tension cables, goes through a transformer that reduces it to 600 volts, and through switches and circuit breakers to a distributing board which distributes it to smaller panelboards supplying various sections of stations and tunnels with current. On the low tension switchboard are two circuit breakers, so wired that they serve as change over switches in the event that the high tension current fails, the low tension current of the third rail automatically is thrown in and keeps the lights burning. Failure of the high tension current or the tripping of a circuit breaker causes an alarm to ring.

Ans. Reduces the high voltage of low amperage to low voltage of correspondingly higher amperage. In the case of the

preceding answer, from 11,000 volts to 600 volts and the amperage correspondingly.

Ques. Why is 600 volts used for lighting?

Ans. Because it corresponds to the third rail voltage to which the lamps are often connected.

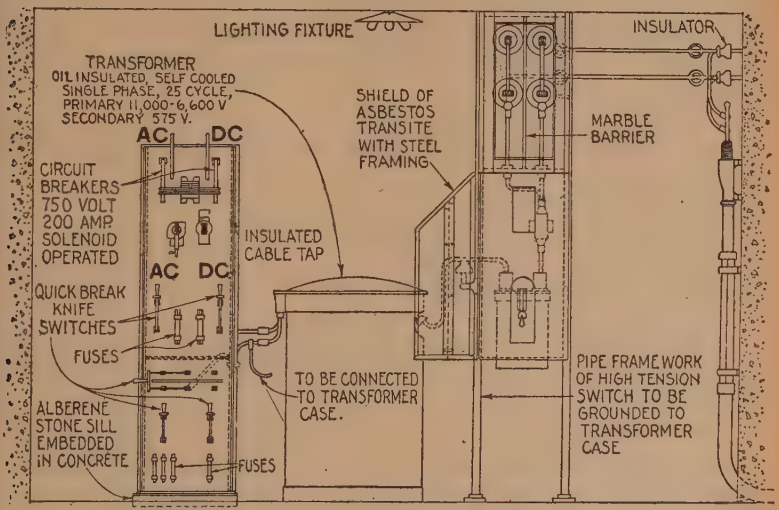


FIG. 6,432.—Subway lighting equipment showing the parts and the arrangement of the apparatus on the switchboards and the methods of connecting.

Ques. How are lamps connected for 600 volt operation?

Ans. Five in series.

Ques. What does the low tension switchboard consist of?

Ans. A panel containing two automatic circuit breakers, or change-over switches, one for *a.c.* and the other for *d.c.* and fuses and switches for controlling the various sections of lights.

The lamps are normally fed from the *a.c.* current of the transformer. A connection is also made to the third rail. The third rail current is *d.c.* If the *a.c.* fail, the *a.c.* circuit breaker opens, and automatically throws in the *d.c.* circuit breaker changing over the connections to the third rail or *d.c.*

To safeguard against the circuit breakers failing to operate, and leaving the station or tunnel in darkness, certain lights are connected directly to the third rails, some to local tracks and some to express tracks, and operate independently of the transformer room connections. Additional means may be provided, such as:

1. One high tension cable being thrown in when another fails;
2. One high tension source coming in when another fails;
3. One low tension source coming in when another fails;
4. Combination of the above.

In addition, lights are staggered and parallel lines are run so that should a wire burn out or a lamp burn out no portion of a station or tunnel will be in total darkness.

Safety Requirements for Handling Subway Lighting Equipment.—Safety is very important in handling subway lighting equipment and in making repairs or tests, as all circuits work on a grounded return and therefore the danger to shock must be eliminated. No circuit should be handled until the switches controlling that circuit be opened.

The high tension disconnect switches must not be touched until the oil circuit breaker is opened and the power house operator notified and he disconnects the cable from the bus.

As all cables, after operating, retain a static charge, a long stick with a chain connected thereto and to ground, is provided in each transformer room with which to take off the charge and to draw out the switches. These switches are normally enclosed in a glass door cabinet.

The panelboards on the station platforms, for controlling the various circuits, are usually of the safety switch type, and no switch can be removed for inspection until it is in the *open* position.

When working on the *d.c.* or third rail side, the fuse connecting the circuit with the third rail should be drawn. Safety must be practiced at all times and everything considered alive.

The concrete floor of platforms is not an insulator and one can get a shock. In the tunnels one must be especially careful as a shock may cause one to fall off a ladder and on to the tracks. The switch controlling the circuit should be opened before getting into the tunnel.

Railroad companies do not want accidents and do not send their employees out on hazardous jobs without precautions, and recklessness is not tolerated.

Requirements of Lighting Material for Subway Lighting.—All lighting material used in subways must be damp proof, dust proof and non-corrodible. The dampness existing underground and in the river tunnels would soon short circuit the apparatus and destroy the ordinary materials.

Conduits, outlet boxes, castings, supports, straps, etc., must be heavily galvanized and all joints well fitted. Rubber gaskets should be used at fixtures.

The fixtures on stations are usually of bronze and those in the tunnels of iron heavily galvanized. The shoe dust carried by trains, running back and forth, of the shoes sliding along the rails, would soon destroy the ordinary brass fixtures.

The wire used is a high grade rubber covered and braided, and passes a rigid inspection. Conduit must be free from burs and sharp edges. The fastenings must be secure to prevent conduit falling on to the tracks and across the third rail.

All wire joints must be soldered and well insulated with rubber tape. Installations, in general, must be made in such manner as will not cause disruption of service nor endanger passengers. Construction men must exercise individual care in working in subways or in under river tunnels.

TEST QUESTIONS

1. *Does the main source depend on the operating source?*
2. *Why is the item mentioned in the previous question important?*
3. *Mention some typical methods of subway lighting?*
4. *Describe a typical modern method.*
5. *What apparatus is contained in the transformer room?*
6. *What does the high tension switchboard consist of?*
7. *Why is 600 volts used for lighting?*
8. *How are lamps connected for 600 volt operation?*
9. *Of what does the low tension switchboard consist?*
10. *What provision is made to safeguard against the circuit breakers failing to operate?*
11. *Give safety requirements for handling subway lighting equipment.*
12. *What are the requirements of lighting material for subway lighting?*

CHAPTER 141

Electric R. R. Car Lighting

Electric cars are lighted usually by the electric current which supplies the power, whether it be overhead, trolley or third rail.

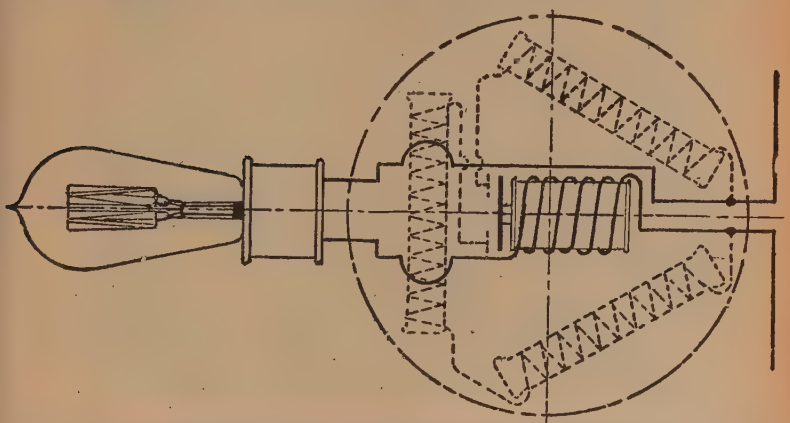


FIG. 6,433.—Lamp with compensating resistance relay. The line current goes through a solenoid which is in series with the lamp and energizes it and causes it to attract an armature. Removing the lamp or the lamp burning out, breaks the circuit and the armature drops onto two contacts, shunting the lamp and throwing its equivalent resistance into the circuit.

The lamps are usually connected in series, the number depending on the working voltage and resistance of the lamps. This series method of car lighting is dependent upon the trolley voltage which sometimes varies over a wide range, with more than proportional variation in light intensity.

The wiring is done in conduit and connections made to avoid jarring loose. Compensating resistances are often installed to prevent all the lights going out should one fail, as in some cases five lamps are connected in series. These compensating resistances are equivalent to the resistance of the lamp and are thrown in circuit by relays when a lamp fails.

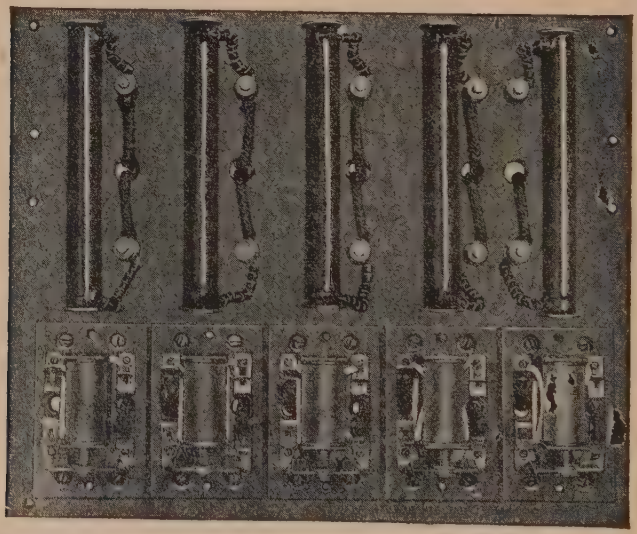


FIG. 6,434.—Electric Service Supplies automatic type compensating series lamp panel shown with cover removed. Compensating panels consist of separate relay and resistance unit for each circuit or lamp. The resistance units are mounted on insulating supports and arranged so that the unit may be readily renewed by the loosening of two nuts. They are supplied with pressed steel ventilated covers. Where the panel is designed for more than one circuit, all parts are mounted on a single insulating base, protected with one cover for the insulating units. The automatic relays have separate dust tight, solid cast iron covers for each individual relay.

Fig. 6,433 shows a lamp having a compensating resistance. Ordinarily the arrangement shown in fig. 6,433 is used, but under certain conditions, as, for instance, lack of head room, it is sometimes impossible to use the self contained fixture, in which case a 5 circuit panel may be placed at any convenient position in the car with wires run from each fixture to this panel.

Compensating panels are also used where one lamp of a circuit is to be divided into two smaller units, as, for instance, in car lighting where the main body of the car is lighted by means of 94 watt lamps, and platform and sign, each by a 46 watt lamp connected in multiple series.

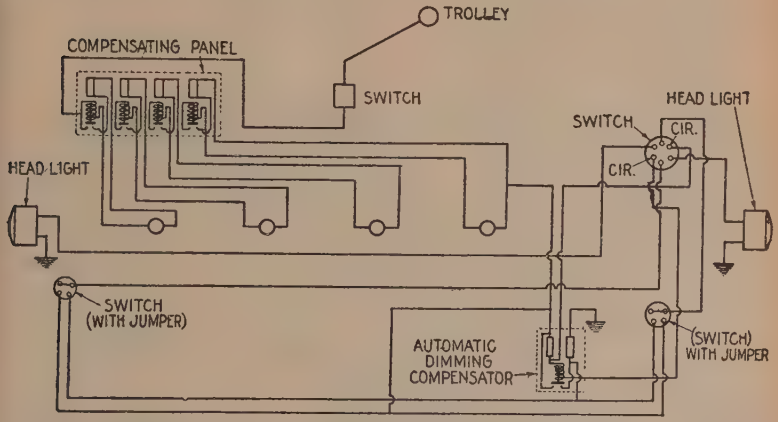


FIG. 6,435.—Diagram of series car lighting system showing hook up with automatic compensating panel. The diagram shows wiring connections for double end car equipped with two head-lights operated in series with one circuit of interior car lights, including automatic dimming, compensating resistance for both head-lights and four circuit compensating panel used in connection with car lights, thus offering a fully compensated single circuit with necessary switches, providing head-light and car illumination.

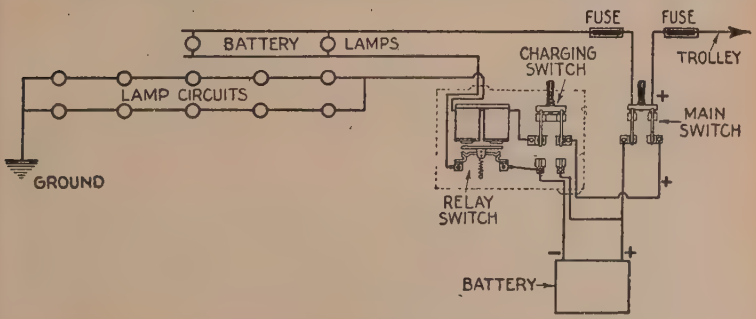


FIG. 6,436.—Diagram of storage battery emergency car lighting system.

As explained in fig. 6,433, the burning out or removal of a lamp in the circuit, due to the breakage of the lamp filament circuit, de-energizes a small solenoid which is in series with resistance units, the latter is substituted for the burned out lamp, and the placing of a good lamp in the socket automatically energizes the solenoid, disconnecting the resistance, and normal conditions are thus restored.

The method of wiring the lamps to a compensating panel is shown in fig. 6,435.

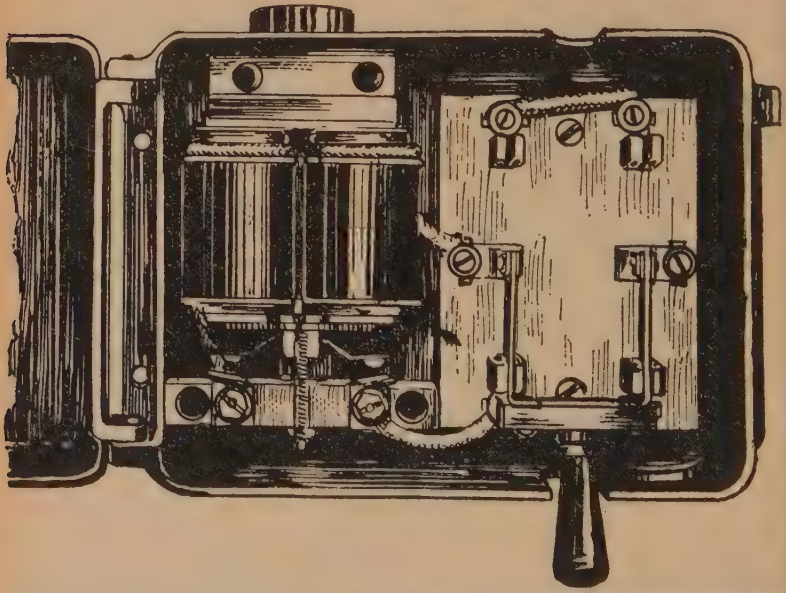
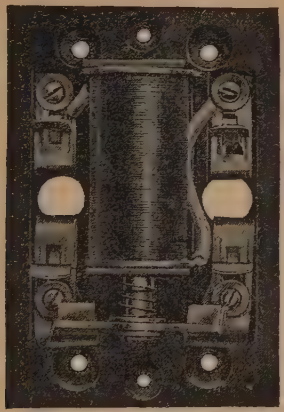


FIG. 6,437.—Consolidated relay and charging switch for emergency car lighting system. The relay and charging switch is for automatically charging auxiliary car lighting battery from trolley and for automatically cutting in a group of lamps on a battery circuit.

Emergency Car Lighting.—In subway cars and others where they may be stalled through the power going off, a device is necessary to give some illumination to the cars while such power is off.

Small storage battery lights are usually installed which are automatically thrown into circuit when the line current fails.



FIGS. 6,438 and 6,439.—Electric S. S. Co. emergency light relay. ***It provides*** an automatic means of cutting in an independent circuit of lamps, operated by a storage battery, in case of failure of the normal power supply. This enables the safe use of electric rear end signal or marker lamps, and in many cases a number of emergency lamps are also placed in the car body. The relays are placed in series with five lamps on the usual 500-600 volt *d. c.* circuit and to all practical purposes do not consume any current or cause any voltage drop. Under normal conditions, the relay is energized and the independent storage battery circuit kept open, but upon failure of the normal current, the armature drops and closes the battery circuit, thus lighting up the emergency lamps.

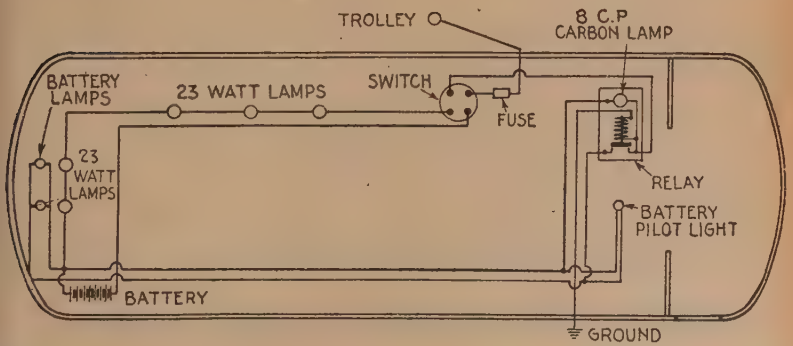


FIG. 6,440.—Electric S. S. Co. wiring diagram for single end car, using relay with pilot light, for operating two rear end signal lamps. Relay pilot light indicates disconnection or failure of battery.

These are operated by a solenoid in series with the line circuit and hold an armature suspended until such current fails, at which time the armature drops and throws the battery lights and current into circuit.

The wiring diagram, fig. 6,436, shows a storage battery system with relay switches and connections, and illustrates how the relay switch automatically throws the storage battery lights into circuit when current is no longer on the trolley. Under these conditions there is no flow of current through the magnet coils and the relay plate falls down upon the contacts

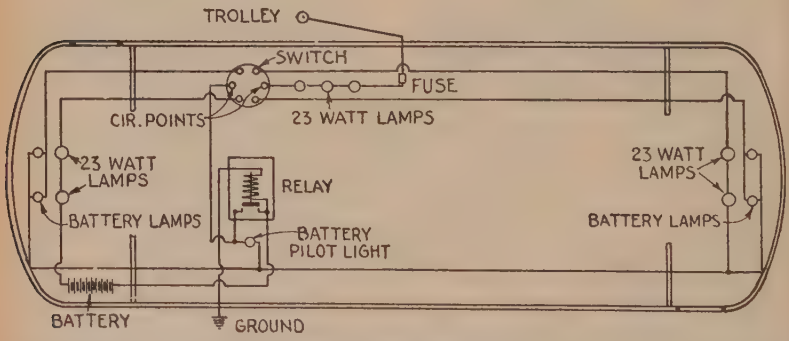


FIG. 6,441.—Electric S. S. Co. wiring diagram for double end car, using relay with emergency lighting circuit for operating two rear end signal lamps with proper switch connections for double end operation.

for the auxiliary lamp circuit, completing the battery circuit. Current flows from the positive terminal of the battery to the main switch, through the fuse to the battery lamps, through the relay plate to the negative terminal of the battery.

The double pole main switch is used to prevent the battery discharging when the cars are in the yard on a dead track, as the main lamps are always turned off in this case, and the battery circuit is therefore broken at this point.

The auxiliary or battery lamps are of six volt type the same as used for automobile lighting, and an ordinary ignition battery used. The operation of the relay and charging switch is shown in fig. 6,436. Here the current comes from the live trolley to the main switch and to the charging switch:

flowing through the magnet coils, the relay is attracted, and it continues to the lamps and to ground. In this position the storage battery is not in circuit. By throwing the switch to the lower position, as shown, current flows from the trolley through the main switch to the storage battery and then through the magnet coils to the trolley lamps and ground; this gives a one ampere flow through the battery; and as the battery is designed for 8 volts, it can be connected in series with the car lamp circuit without dimming the lamps materially. When the battery has been charged, the switch is thrown back to the upper position.

The accompanying diagrams show various hook ups for single and double end cars.

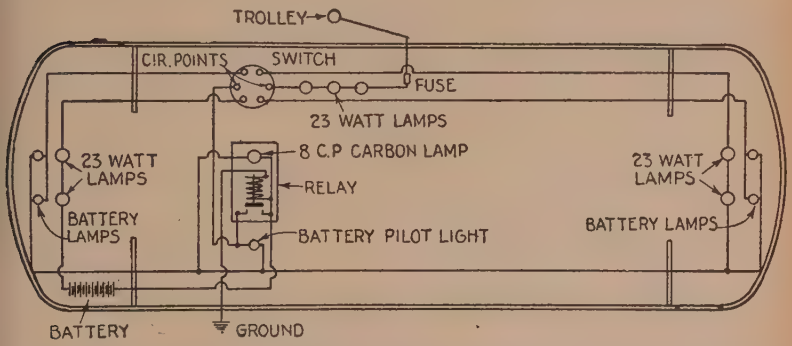


FIG. 6,442.—Electric S. S. Co. wiring diagram for double end car using relay having pilot light, indicating disconnection or failure of storage battery, for operating two rear end signal lamps with switch connections for double end operation.

TEST QUESTIONS

1. *What is the usual current source for the lighting of electric railroad cars?*
2. *How are the lamps generally connected?*

3. *What determines the number of lamps connected in series?*
4. *What is a compensating panel?*
5. *What system of wiring is used?*
6. *Why are compensating resistances used?*
7. *Describe the operation of a compensating resistance.*
8. *Describe the emergency system of car lighting.*
9. *Draw diagrams showing various hook-ups of single and double end cars.*

CHAPTER 142

Axle Lighting Systems

The term "axle" as popularly applied to car lighting systems includes such equipments as those *having a dynamo under each car belted to a pulley on one of the car wheel axles and wired to charge a storage battery.*

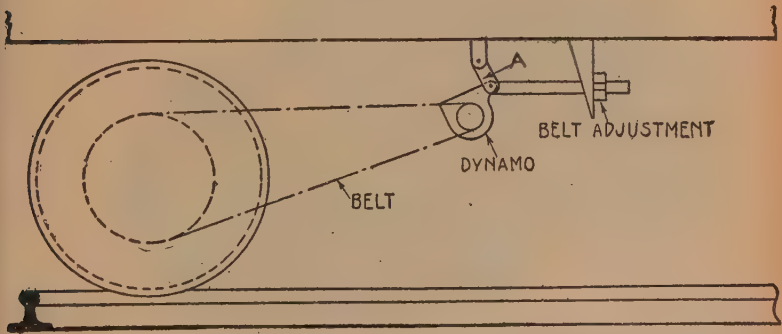


FIG. 6,444.—Essential features of one method of dynamo suspension in axle lighting system. ***As shown,*** the dynamo is supported at one corner of its frame by the adjustable link, A, in such a manner that it is free to swing toward or away from the driving axle. The suspending link is so placed that the belt draws the dynamo out of the diagonal position in which it would naturally hang, thus putting a definite tension on the belt, just sufficient to absorb the power required. It is obvious that when the pull on the belt exceeds that due to the offset suspension of the dynamo that the dynamo will be drawn toward the axle and the belt allowed to slip.

Accordingly the essential parts of such a system are:

1. Dynamo;

2. Axle pulley belt drive;
3. Storage battery;
4. Discriminating cut out, or reverse current circuit breaker;
5. Regulators;
6. Lighting fixtures;
7. Pole changer;
8. Switches, fuses, etc.

Dynamo.—This machine is mounted under the car body with

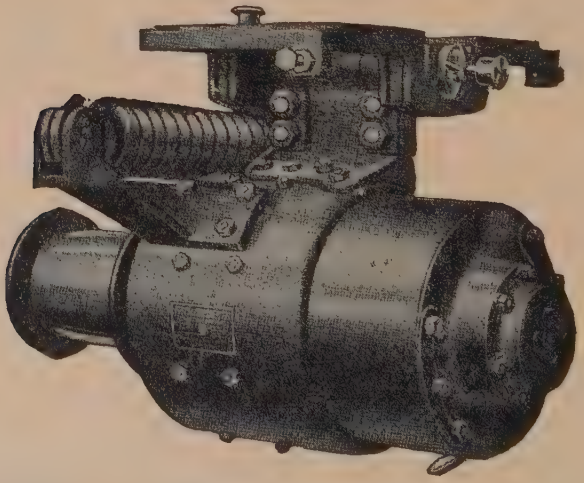


FIG. 6,445.—Safety C. H. & L. dynamo with tension spring.

belt drive as shown in fig. 6,444. Sometimes the dynamo is mounted on the truck frame.

When the dynamo is mounted on the car body, there must be included certain features for successful operation.

The drive must be so arranged that the belt tension device does not place an abnormal strain on the belt when the distance between the center

of the driving pulley and the center of the driven pulley is increased by the car rounding a curve.

The dynamo is pivoted to the mounting foot and the belt held in tension by

1. Tension spring, or
2. Compression spring.

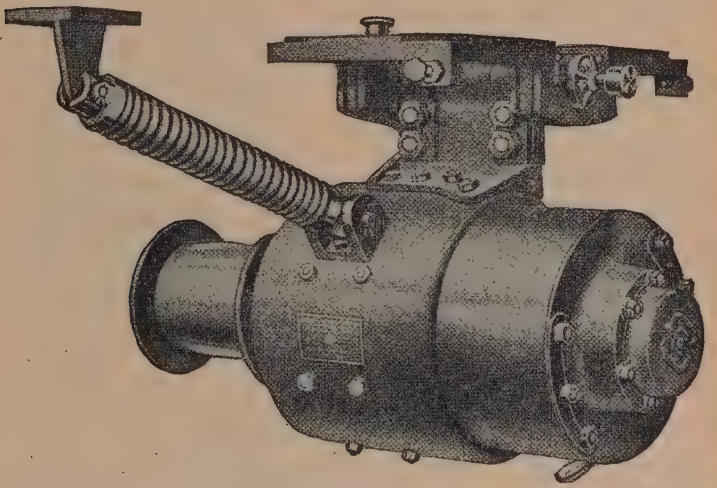


FIG. 6,446.—Safety C. H. & L. dynamo with compression spring.

These two arrangements are shown in figs. 6,445 and 6,446 and the belt tension is taken care of by an arrangement of spring which gives practically constant belt tension throughout any movement of the dynamo caused by belt stretch or the car rounding a curve.

Uniform belt tension is obtained by arranging the spring attachment to the dynamo so that when the belt pull occasioned by the weight of the

dynamo increases, the belt pull caused by the spring decreases; the sum of the spring pull and the weight pull being constant.

The compression spring shown in fig. 6,446 is used only on suspensions where it is desired to have the center line of the pulley on the center line of the car.

The action of the uniform belt tension device is shown in figs. 6,447 to 6,450. Referring to these figures, the dynamo is hung from the shaft C

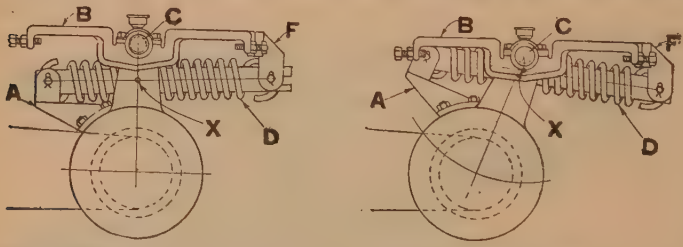


FIG. 6,447.—Position of dynamo with tension spring when distance between the axle pulley and suspension frame is shortened.

FIG. 6,448.—Position of dynamo with tension spring when distance between the axle pulley and suspension frame is lengthened.

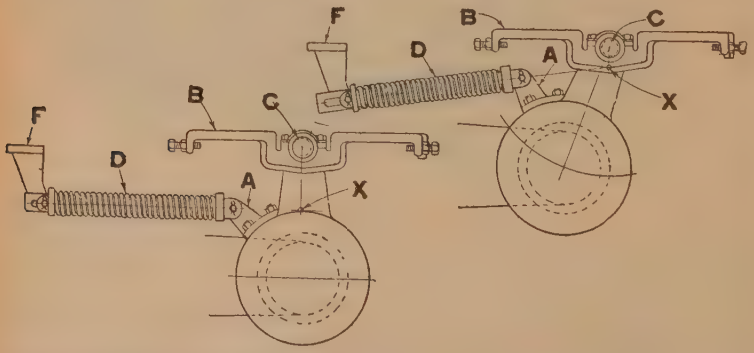


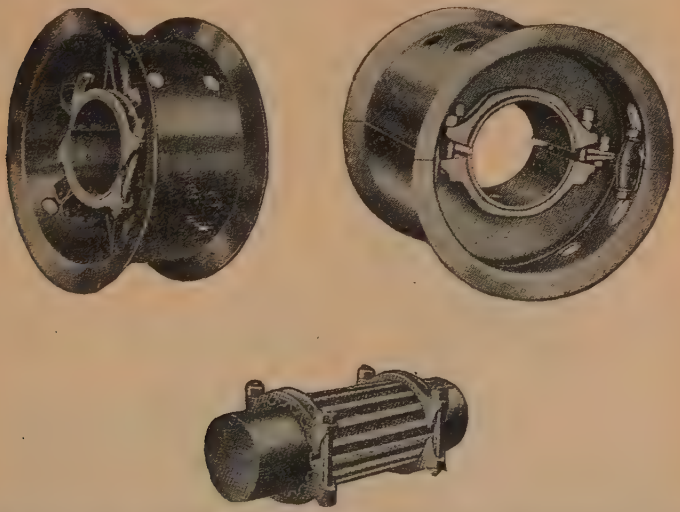
FIG. 6,449.—Position of dynamo with compression spring when distance between the axle pulley and suspension frame is shortened.

FIG. 6,450.—Position of dynamo with compression spring when distance between the axle pulley and suspension frame is lengthened.

To push the dynamo toward the truck requires more force the farther back the dynamo is pushed, as this action makes it necessary to raise the weight of the dynamo. If no spring be used, the belt tension would depend on the position of the dynamo, increasing as the dynamo is pulled by the belt toward the truck.

The same is true if an ordinary compression or tension spring be used, that is, as soon as the belt stretches or the distance between the dynamo and the axle varies, the pull of the spring changes the pull on the belt.

The spring is fastened at one end to the dynamo and at the other end is held stationary by a bracket F, attached to the suspension plate or to



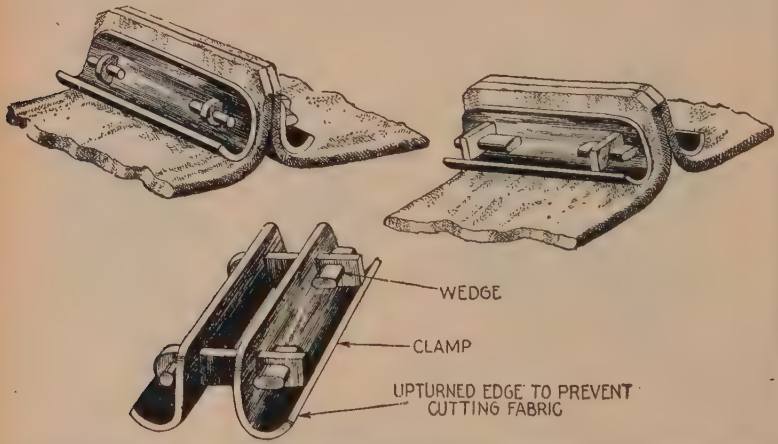
FIGS. 6,451 to 6,453.—"Underframe" pulley construction. Fig. 6,541, spoke type axle pulley; fig. 6,452, disc type axle pulley; fig. 6,453, axle pulley bushing.

the center sill of the car. This spring swings the dynamo away from the truck, as the suspension lugs on the dynamo act as a lever for the spring to revolve the center of the dynamo around the suspension shaft C.

The lever arm with which the spring pulls is the distance between the center of the shaft C, and the point X. When the dynamo hangs vertical as in figs. 6,447 and 6,449, this distance is comparatively large and the spring exerts considerable force.

When the dynamo swings toward the truck as in figs. 6,448 and 6,450, this distance between center of shaft C and X becomes smaller, and the force of the spring on the dynamo is less. In the latter position, however, the weight of the dynamo which is converted into belt pull has become greater.

The strength of the spring and its point of attachment to the dynamo are so selected that the increase in belt pull from the weight of the dynamo as it moves toward the truck, is counter-balanced by the decrease of the force of the spring as its point of application to the dynamo is changed relative to the center.

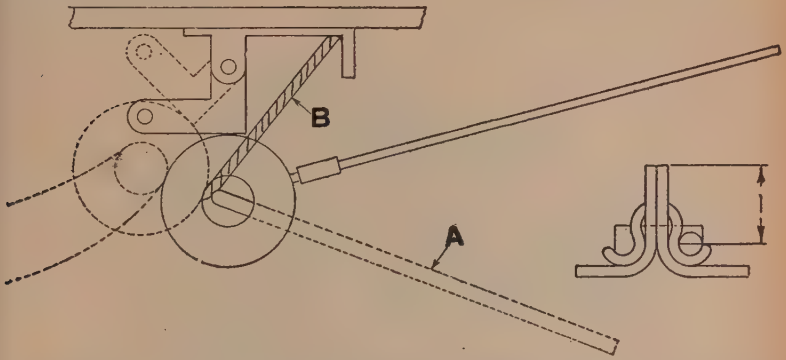


FIGS. 6,454 to 6,456.—Safety belt fastener and method of attaching. This fastener requires that the two ends of the belt be turned up perpendicular to the run of the belt, the ends being held firmly together by a plate on each side and two links extending through holes in the plate and punched holes in the belt. These links are held in place by wedges which are driven through slots in the links. The inclined surface of the wedge furnishes a means by which the side plates may be driven up tight against the belt under considerable variation in the belt thickness. A suitable clamping may be obtained for any thickness of belt by the use of one of three different lengths of link marked 4 ply, 4½ ply and 5 ply respectively. ***To apply fastener,*** cut the ends of the belt square across at the correct length. Draw lines square across the belt 1 inch from each end. Punch the holes for fasteners on these lines, using as a template, a fastener or template furnished with the belt cutter. A special belt punch should be used for making the holes the correct size and shape.

On railroads where there are a number of very sharp curves to contend with, it may be desirable to mount the dynamo so that the centers of the axle pulley and dynamo pulley are on the center line of the car.

This center line mounting is used to obtain the widest possible axle pulley; the use of a wide axle pulley may prevent the losing of the belt on very sharp yard curves.

The suspension arrangement shown in fig. 6,446 with the compression spring attached to the dynamo and to a bracket on the center sill is used where it is desirable to have a center line suspension.



FIGS. 6,457 and 6,458.—Method of pulling on belt. ***To put on the belt,*** swing the dynamo toward the truck, with the dynamo pry A, and block in upper position by wood piece B (20 ins. by 3 ins. by ⅞ ins. standard width).

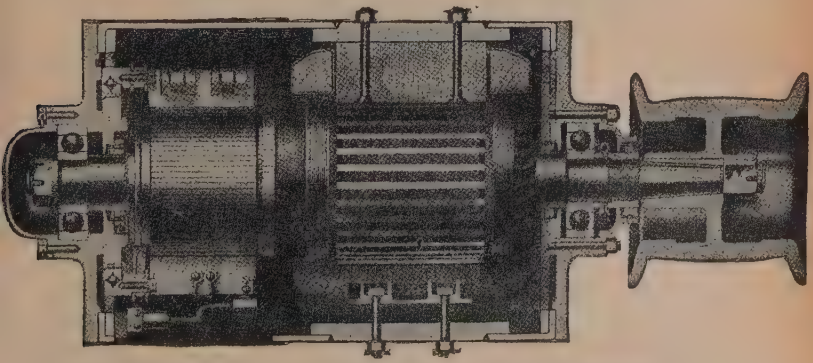


FIG. 6,459.—Safety C. H. & L. dynamo; sectional view showing construction.

Where this feature is not desired, the suspension is as shown in fig. 6,445, with tension spring attached to the dynamo and to the suspension plate. The dynamo is usually of the four pole shunt wound type as shown in fig. 6,459 connected as shown in fig. 6,461.

STORAGE BATTERY.—IT IS NOT NECESSARY HERE TO GO INTO THE DETAILS OF STORAGE BATTERY CONSTRUCTION AS THIS HAS BEEN COVERED AT GREAT LENGTH IN ANOTHER VOLUME OF THIS SERIES. The size of battery used depends upon the number and size of the lamps to be lighted, and usually

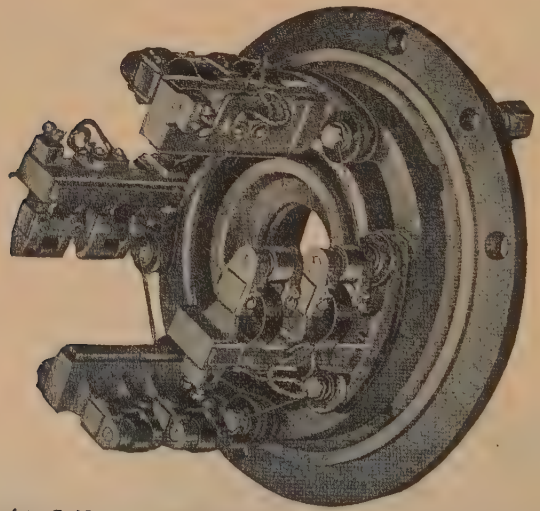


FIG. 6,460.—Safety C. H. & L. pole changer brush rigging. The direction of current from the dynamo is kept constant by rotating the brushes through an angle of 90° whenever the direction of rotation of the armature is changed. The pole changer may be taken off the head by springing out from its groove the snap ring which holds it on.

consisting of 16 to 20 cells arranged in groups of 2 or 4 for easy handling or removing.

A typical battery unit consists of two cells. These are combined into groups of 8 or 10 and connected in series and form the battery for car lighting.

Control and Regulating System.—There are numerous duties which have to be performed by automatic devices in the proper operation of a dynamo storage battery lighting plant, the devices which perform these operations being known as:

1. Pole changer;
2. Discriminating cut out or reverse current circuit breaker;
3. Dynamo regulator;
4. Lamp regulator.

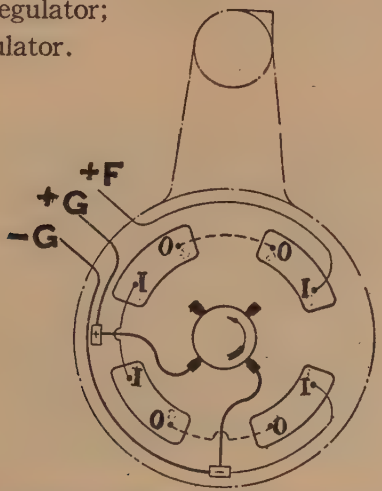


Fig. 6,461.—Diagram of field coil connections of safety C. H. & L. "axle" lighting system.

Pole Changer.—This device consists of a double pole double throw switch hinged in the center and thrown to one side or the other by a projection on a wheel mounted on the dynamo shaft. When the direction of the train reverses, the switch is thrown and keeps the direction of the current constant into the battery.

Discriminating Cut Out.—This is *an automatic switch for throwing the dynamo in and out of circuit*, as shown in fig. 6,462.

When the dynamo reaches the required speed and therefore attains the proper voltage, the iron core is drawn up into the coil and closes the switch causing the dynamo to supply the current.

When the train slows down a very marked degree or stops altogether, the magnetic coil becomes weakened and lets the iron core drop and it disconnects the dynamo and throws the battery into circuit.

Briefly, the discriminating cut out disconnects the dynamo from the battery when the voltage of the dynamo, by reason of decreasing speed, becomes lower than the voltage of the battery—otherwise the battery would discharge through the dynamo.

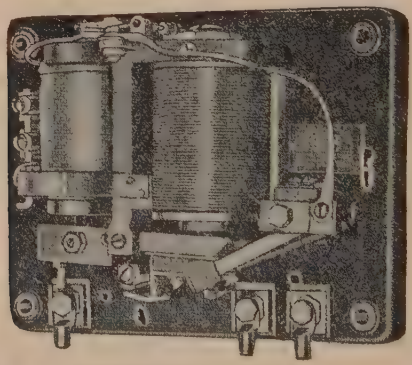


FIG. 6,462.—Safety C. H. & L. discriminating cut out or automatic switch. *It is* of the closed magnetic circuit type with pivoted armature. It has three voltage coils and one series coil, so arranged that when the dynamo voltage equals that of the battery the armature is lifted and the circuit closed.

Dynamo Regulator.—This consists of a pile of carbon blocks, or other arrangement, which offer a resistance, and are compressed or released, and either decrease or increase the resistance in the circuit by plungers controlled by the varying voltages caused by the carrying speeds of the train and in that way keep it constant. Figs. 6,464 and 6,465 show the construction of a dynamo regulator.

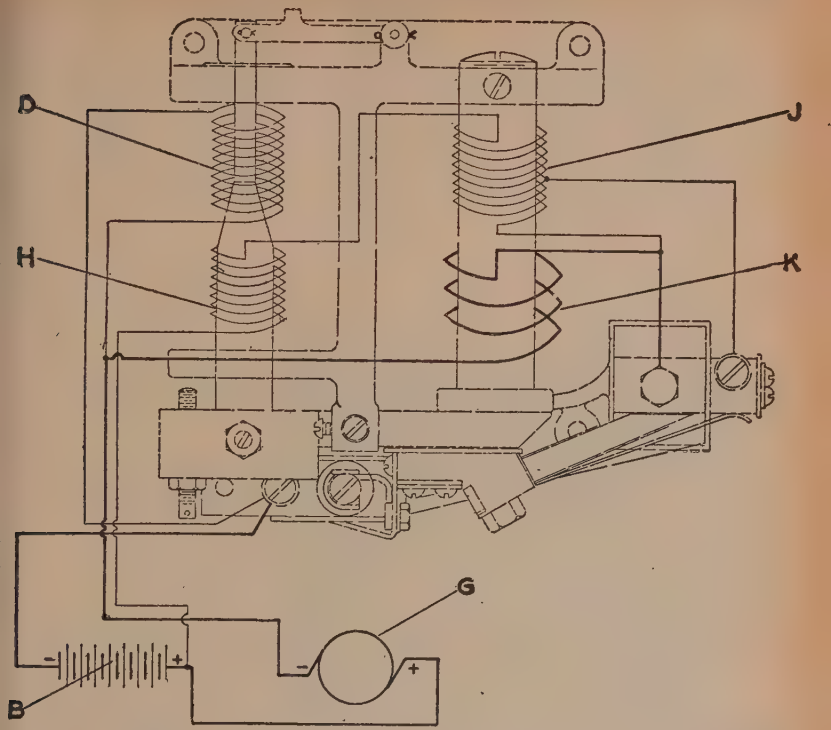
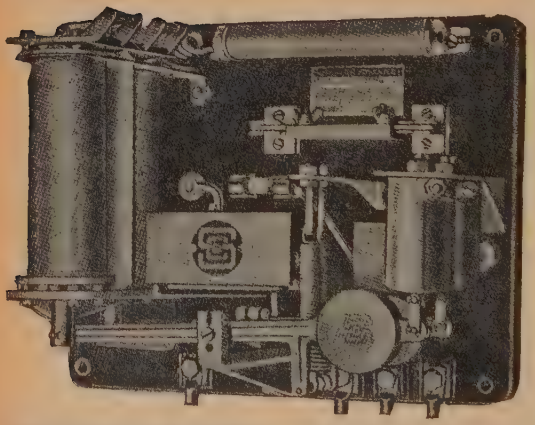
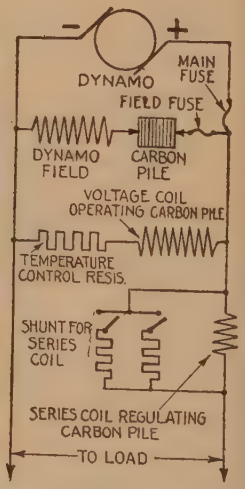


FIG. 6,463.—Diagram of Safety C. H. & L. discriminating cut out. The coil D, is connected across the contacts of the switch so that the voltage impressed across it is the difference between battery voltage and dynamo voltage, and if the dynamo be not operating, the full battery voltage is available. The pull of this coil on the auxiliary plunger locks the switch in an open position. At the same time the current from the battery which energizes this coil also serves to energize the field of the dynamo so that it will always build up in the proper direction. The coils J and H, are in series across the dynamo so that as the dynamo builds up, coil J, tends to close the switch while coil H, serves to replace coil D, which becomes inoperative as the dynamo voltage approaches that of the battery. The design of these coils is such that the correct balance is obtained at any battery voltage encountered in service. Consequently when the armature is set with the proper gap, the switch closes when the dynamo is charging the battery and also serves to neutralize coil J, when the battery attempts to discharge through the dynamo. The tap from coil J, brought out to the contact on the switch, serves to reduce the strength of coil J, so that a very small discharge from the battery will open the switch. It is thus possible to eliminate the carbon contacts formerly used. Due to the fact that the operation of this switch depends upon the balancing of the voltage coils D, H and J, the effects of temperature changes in the coils cancel each other. It is therefore not necessary to place resistances with zero temperature co-efficients in series with the coils to obtain the same operation under various changes in temperature.

Lamp Regulator.—The object of this regulator is *to maintain the lamp voltage constant with changes in the battery voltage.* With the battery run down, the lamps would burn dimly and with the battery fully charged perhaps burn the lamps out.

The regulator automatically varies the resistance in the circuit and





FIGS. 6,464 and 6,465.—Safety C. H. and L. dynamo regulator and wiring diagram. The dynamo is controlled to give the proper battery and lamp current through changes in speed and load by the amount supplied to the shunt field. This field current is controlled by the resistance of the carbon pile in series with the field. The resistance of this carbon pile is governed by the pressure exerted on it by levers which are operated by the plungers of current and voltage magnets. The windings of the series coil carry the total current output of the dynamo; if the current output tend to vary from that which the regulator is set to maintain during the early stage of battery charging, the plunger of the series coil through its lever, changes the pressure of the carbon pile, thereby reducing or increasing the field strength and holding the dynamo current to its proper value. If the voltage tend to rise above that for which the regulator is set to maintain, the plunger of the voltage coil through its lever, reduces the pressure on the carbon pile and holds the voltage to its proper value, thereby insuring reliable battery protection and adequate lamp supply. The series coil is set to hold the current value at the rated output of the dynamo. The voltage coil is set for a maximum voltage of 2.4 volts per cell, or 38.5 volts on a 16 cell equipment of lead batteries. With this as a maximum voltage, the voltage coil when effecting the regulation, prevents overcharging of the batteries, since the current to the batteries will then automatically taper down to a low value as the batteries become fully charged.

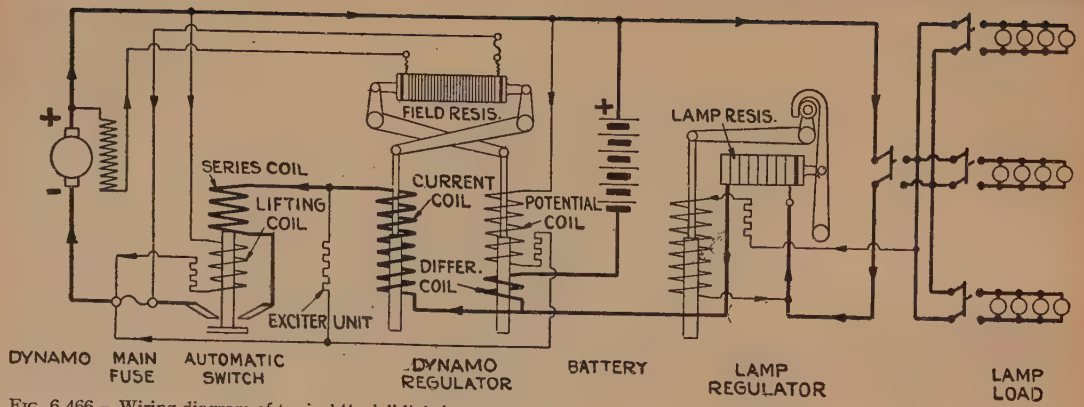


FIG. 6,466.—Wiring diagram of typical "axle" lighting system.

NOTE.—***Lamp regulator adjustments.*** The only adjustments that can be made on lamp regulators are the pressure on the carbon pile, the spring tension and the air vent on the dashpot. To adjust the carbon pressure, have no current on the magnet, and disconnect the dashpot by removing the nut on the top, then pull down on the armature and screw up the knurled carbon adjusting nut on the left side of the regulator until the spring arm will just barely go back against its stop. Then loosen the carbon adjusting nut one half turn, which will allow the arm to go back freely against the stop. To adjust the spring tension, short circuit the carbon pile across 2 and 3, fig. 6,467. Have that voltage which it is desired to maintain across the lamp mains; that is, from 1 to 4. Usually this voltage will be either 30 or 40. Now adjust the spring tension by the spring adjusting screw until the armature will remain in any position throughout its stroke. Replace the dashpot and remove the short circuit from 2 and 3 and the regulator is ready to operate. No short circuiting device for the carbons is required. Special carbons are used which, when properly adjusted with a 30 volt equipment, give a total drop of less than 1½ volts at the maximum lamp load for the given regulator. If the drop be found to be greater than this, the knurled carbon adjusting nut should be tightened one or two notches more.

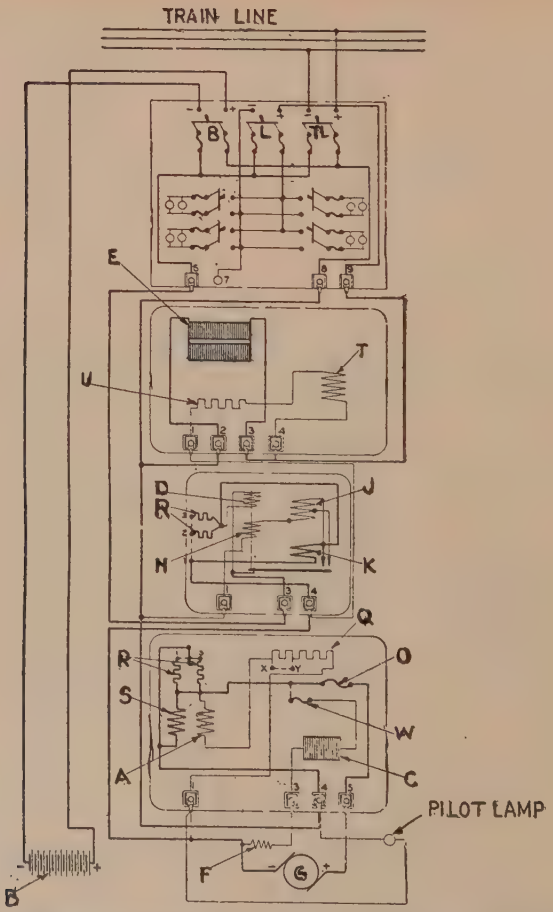


FIG. 6,467.—Wiring diagram of safety C. H. and L. regulator with main switch control of lamp regulator. *The parts are:* A, shunt regulating coil; B, battery; C, field resistance carbons; D, holding out coil for main switch; E, lamp resistance carbons; F, generator field; G, generating armature; H, balancing coil for main switch; J, lifting coil for main switch; K, series coil for main switch; L, main light switch; TL, train line switch; O, main fuse; Q, resistance for coil A; R, shunt resistance; S, series regulating coil; T, lamp regulating coil; U, resistance for T; W, field fuse. Note. Connect XY, to charge lead battery open for Edison battery.

keeps the lamps burning at proper brilliancy. Fig. 6,468 shows one form of lamp regulator.

The assembly, connection and operation of the various devices comprising the control and regulating system are shown in fig. 6,467.

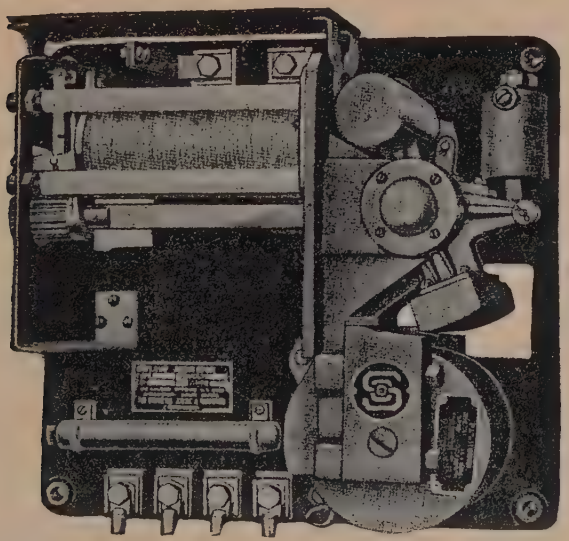


FIG. 6,468.—Safety C. H. & L. lamp regulator. ***It consists of*** one, two, or three piles of carbon discs in series with the lamps, the two or three piles being in parallel. The pressure on these carbons, and therefore their resistance, is governed by the armature of a magnet, the winding of which receives lamp voltage. The carbons are compressed by an adjustable spring connected to a link acting through a lever connection. The pull of the spring is opposed by the pull of the electro-magnet, which is connected directly across the lamp mains and is so designed that the armature will stay in any position throughout its stroke when the lamp voltage is right. When the lamp voltage is high, the magnet becomes stronger and pulls the armature down against the pull of the spring and reduces the pressure upon the carbons, increasing their resistance and bringing the lamp voltage back to normal. If the lamp voltage be low, the magnet becomes weakened, the spring pulls the armature back and, through the lever connection, exerts enough pressure on the carbon piles to decrease their resistance and bring the lamp voltage back to normal.

TEST QUESTIONS

1. *Define the term "axle" as popularly applied to car lighting systems.*
2. *Name the essential parts of an axle lighting system.*
3. *How is the dynamo mounted?*
4. *How is the dynamo drive arranged?*
5. *Name two ways in which the dynamo is pivoted.*
6. *How is uniform belt tension obtained?*
7. *Describe the method of attaching belt fasteners.*
8. *What is the best method of mounting the dynamo on railroads where there are a number of very sharp curves?*
9. *Name the devices used for the control and regulating system.*
10. *Describe a reverse current circuit breaker or discriminating cut-out.*
11. *Why is a discriminating cut-out necessary?*
12. *Of what does a dynamo regulator consist?*
13. *What is the object of a lamp regulator?*
14. *Describe the construction and operation of a lamp regulator.*

CHAPTER 143

Locomotive Head Light Systems

The problem of lighting electric trains does not involve the generation of the current as this is obtained from the third rail or overhead line. However, on steam roads, *there must be provided a current source.*

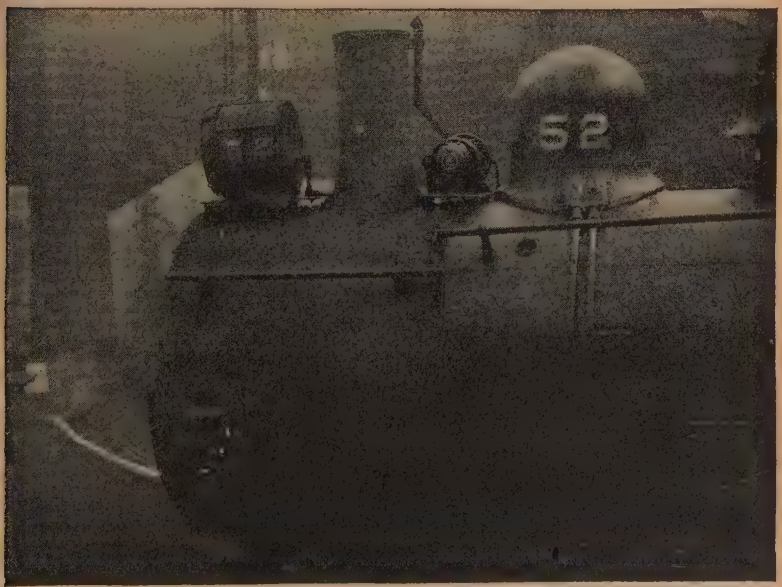
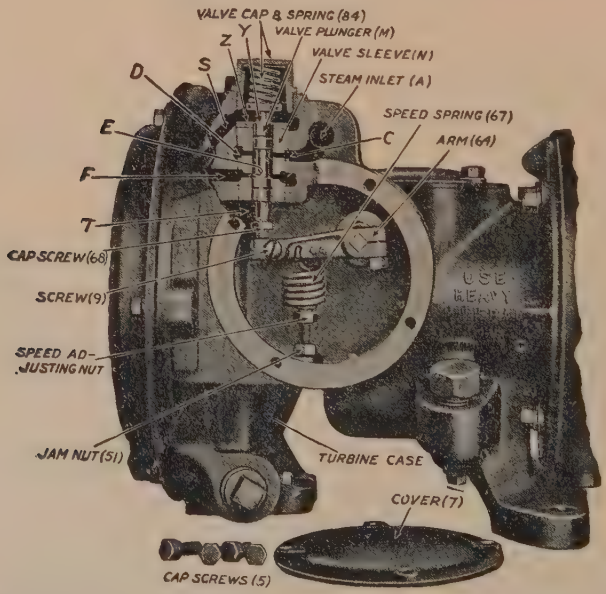


FIG. 6,469.—Westinghouse 500 watt head light unit installed in locomotive.

The current may be obtained either by the "axle system" described in the preceding chapter or from a turbine driven dynamo located on top of the locomotive boiler forward of the smoke stack. This arrangement, though originally intended only to furnish current for the head light, is now sometimes used to light the entire train.

The lighting of the entire train by a single turbine dynamo



FIGS. 6,470 to 6,472.—Keystone turbine with side cover and valve cap removed; turbine case broken away to show valve mechanism. ***In operation,*** steam enters at A, passes through the strainer B, into the passageway C, through the ports D, and travels between the valve plunger and the valve sleeve to the port opening E. The amount of steam passing through this port E, is regulated by the fly ball governor which controls the valve and thus automatically regulates the speed of the machine by proportioning the quantity and pressure admitted to the nozzle, etc., to keep uniform speed and voltage for any load. The valve is of the piston type. High pressure steam (boiler pressure) is maintained in the passageways C and D, and around the reduced central portion of the valve plunger M. The enlarged ends of this plunger are of equal diameter and area, and the slight leakage of steam between the plunger ends and the valve sleeve N, escapes into the cavities S and T, and into the turbine case where the steam pressure is slightly above that of the atmosphere. This leakage of steam tends to keep the valve plunger clean.

set has some advantages over the individual dynamos used in the axle drive system.

It provides greater dependability of operation, and because of its simplicity and higher efficiency, is more economical in first cost, operation and maintenance. In addition to lighting the entire train, the head end dynamo also furnishes current for locomotive lighting. Moreover the speed of the dynamo being maintained constant by the turbine governor, the lights burn at constant brilliancy regardless of the speed of the train.

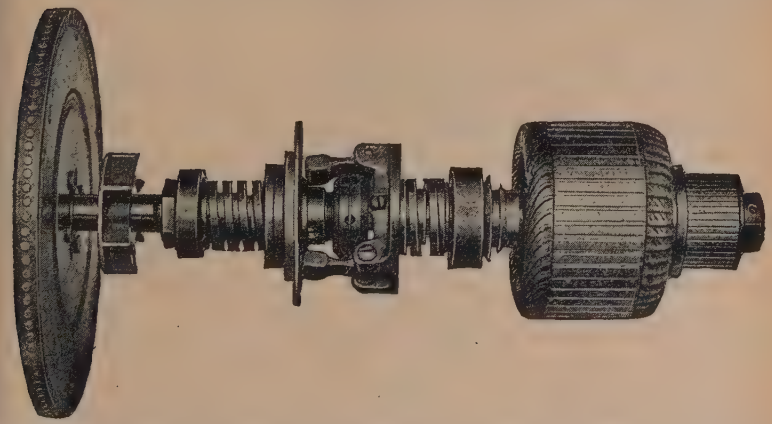


FIG. 6,473.—Keystone rotating element, showing wheel, baffle fan, governor, including oiling disc, safety spring, ball bearings and armature, mounted on the shaft.

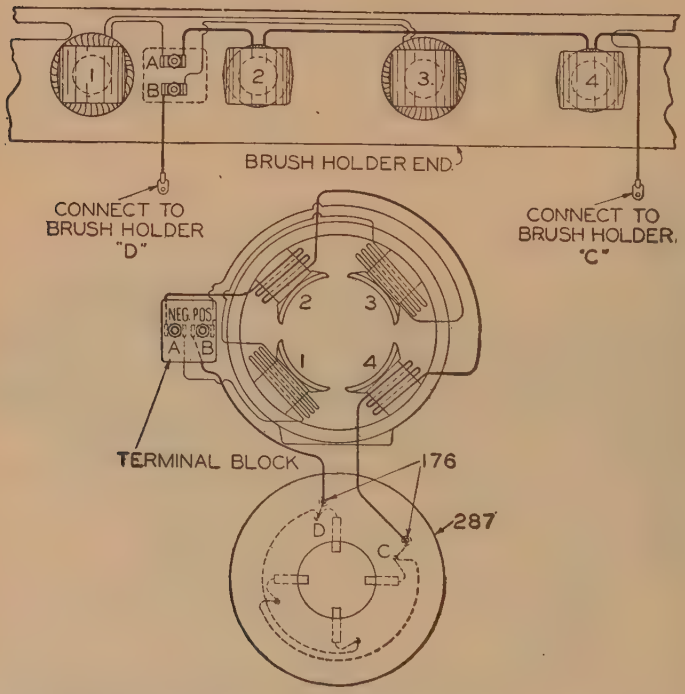
In the axle system the voltage varies somewhat, resulting in dim periods of illumination and sometimes an objectionable flicker of the lights when the discriminating cut out or reverse current circuit breaker operates to disconnect the dynamo from the battery.

Train lighting systems of the locomotive head light type may be installed with or without batteries.

The simplest and least expensive installation is the non-battery system.

This consists of a single circuit running the length of the locomotive and train, with suitable flexible connectors between the locomotive and train, and between cars, together with control switches and fuses properly located to operate and protect the circuit. Two wire or three wire

circuits may be used, depending on the length of the train. For short trains, a two wire circuit is satisfactory. For trains of greater length



FIGS. 6,474 and 6,475.—Wiring diagram of Keystone dynamo field connections. All coil connecting lead wires should lie close to and in the rear portion of the magnet frame, and away from the revolving armature, and they should be brought to the terminal block at the left side of the dynamo. The terminals are stamped shunt and series to facilitate proper connections. With the coils properly connected, as shown in the diagram, and then properly magnetized, opposite pole faces should have like polarity, and adjacent pole faces should have unlike polarity. If, for any reason, the above relation be not found, the following test will locate the trouble: With *d.c.* from an external and independent circuit of sufficient voltage to definitely influence a compass needle, and with external circuit wires connected to binding post B, and right hand brush holder C, the faces of poles No. 1 and No. 3 should indicate like polarity quite strongly. Shift external circuit connection from binding post B, to binding post A, leaving connection at C, as for previous test, thus causing current to flow in the series coils only; the faces of poles No. 2 and No. 4 should indicate like polarity quite strongly, and opposite to that shown by faces of poles No. 1 and No. 3 as just tested; thus pole faces should show alternately N and S, polarity.

than three or four cars, the three wire circuit is recommended, as it insures nearer uniform voltage throughout the length of the train.

The battery system, which provides a source of current when the locomotive is disconnected from the train, while more expensive in both installation and maintenance cost, provides the flexibility that is desirable and necessary for some installations.

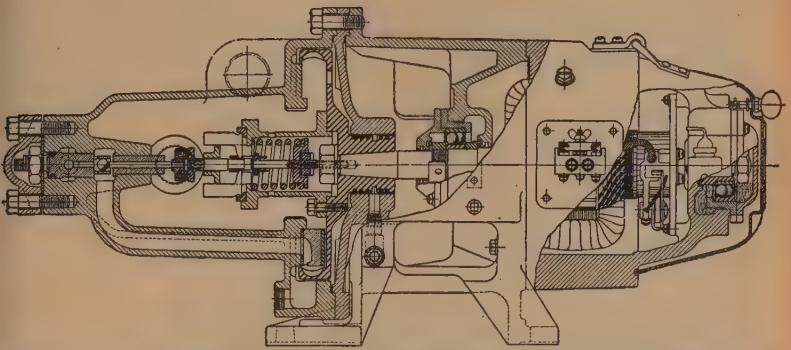


FIG. 6,476.—Westinghouse 32 volt, 500 watt locomotive head light unit; sectional view showing interior construction. The speed of the unit is controlled by a fly ball governor which is bolted to the turbine disc as a complete unit. This governor acts directly upon the governor valve stem without the use of any intermediate linkage. By means of this simple and reliable construction very close and stable regulation is obtained. The governor valve consists of a single seat against which a steel ball acts, the position of which is fixed by the governor, thus, admitting the exact amount of steam required for the load. A metal labyrinth ring gland is used to seal the shaft where it enters the turbine cylinder. The rings are of the piston type and require no adjustment. The dynamo is wound to deliver 32 volts *d.c.* from no load to full load at approximately 4,000 *r.p.m.* and will carry its rated load of 500 watts continuously.

With the non-battery system, electric light will, of course, be provided only when the locomotive is connected to the train, while with the battery system light may be made available either for individual cars or for the entire train, for periods of five hours or so, when the locomotive is disconnected from the train.

The Power Plant.—The source of current as before mentioned consists of a turbine driven dynamo designed as a

FIG. 6,477.—Entire train illuminated by "Sunbeam" turbine driven dynamo.

compact unit suitable for mounting on top of the locomotive boiler forward of the smoke stack. A typical set of this kind is shown in figs. 6,469 and 6,478.

Voltage regulation is accomplished by means of a centrifugal governor located in the body of the machine. It maintains turbine and dynamo speed practically constant, regardless of varying loads or steam pressures.

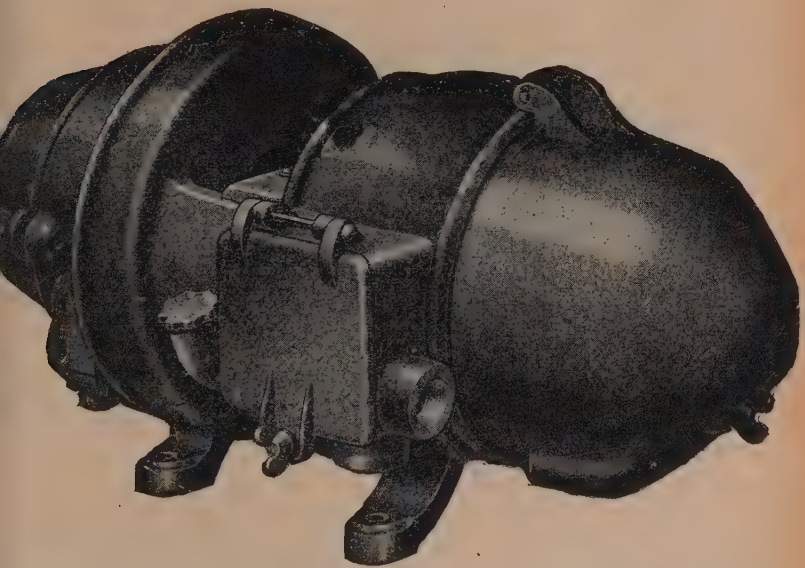
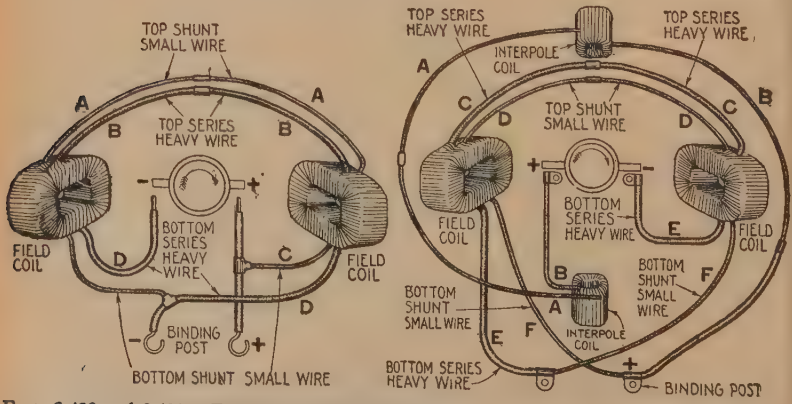


FIG. 6,478.—Sunbeam four pole turbine driven dynamo. It is a four pole, compound wound dynamo, having a capacity of 800 watts at 32 volts. This capacity is ample for automatic train control, head lights, cab lights, classification and marker lights. It operates at a speed of 2,800 *r.p.m.* In its design it complies in all respects with Association standards as a head light dynamo and train control dynamo. The armature and turbine wheel are carried on a single shaft, which rotates on ball bearings, one bearing between the turbine wheel and armature, and one at the armature end of the shaft. The dynamo frame, turbine case and supporting feet are cast in one piece, insuring rigidity and perfect bearing alignment. The turbine wheel is a steel disc with buckets welded on it. It can be safely run at the highest possible speed it can attain under any condition. It will deliver full output at uniform voltage, at from 100 lbs. to the highest boiler pressures now used. When in operation only sufficient steam is admitted by the governor valve to generate the electrical energy required. Steam consumption is in proportion to the load. It operates on a wide range of steam pressures.

Located at the top of the turbine body, the governor valve or main steam valve is mounted as a separate unit. It works in a renewable cage of nickel alloy.

The diagrams figs. 6,480 and 6,481 show arrangement of field coils for the 3 *kw.* and 4 *kw.* machines respectively.

FIG. 6,479.—Westinghouse 32 volt, 500 watt locomotive head light unit. ***It consists of*** a single impulse steam turbine and an enclosed *d.c.* dynamo built together as a single unit. There are two self aligning ball bearings carried by the dynamo end brackets. The turbine rotor is mounted on the end of the dynamo shaft which is tapered and held in place by a lock nut and washer.



FIGS. 6,480 and 6,481.—Field diagram of Sunbeam turbine driven dynamo sets. Fig. 6,480 3 *kw.*; fig. 6,481, 4 *kw.*

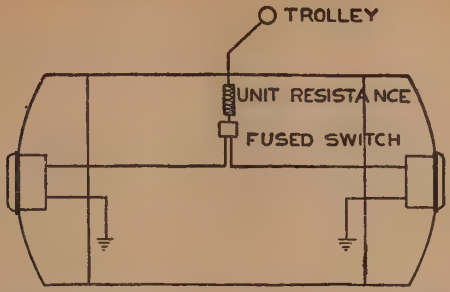


FIG. 6,482.—Head light wiring diagram for mine locomotives. 1, double end equipment, circuit voltage greater than head light lamp voltage; each lamp burns singly.

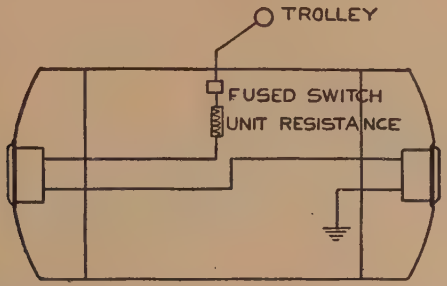


FIG. 6,483.—Head light wiring diagram for mine locomotives. 2, double end equipment, both head lights burn at same time, circuit voltage greater than that of combined lamps.

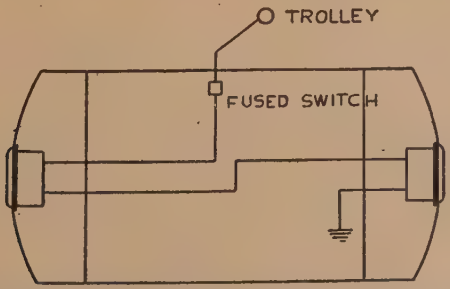


FIG. 6,484.—Head light wiring diagram for mine locomotives. 3, double end equipment, head light lamp voltage one-half that of circuit voltage; both lamps burn at same time.

TEST QUESTIONS

1. *Name two ways of obtaining the current used in a locomotive lighting system.*
2. *Give comparison of lighting entire train by single turbine dynamo or by individual axle drive dynamo.*
3. *Is the voltage constant in the axle system?*
4. *In what two ways may train lighting systems of the locomotive head light type be installed?*
5. *Where should two wire and three wire circuits be used?*
6. *What is the objection to the non-battery system?*
7. *How is the voltage regulation accomplished?*
8. *What is the usual voltage employed in locomotive lighting systems?*

CHAPTER 144

Car Heating

Electric cars are usually heated by electric heaters. These are made of coils of wire wound on porcelain spools placed in suitable containers and fastened under the seats.

FIG. 6,485.—Consolidated heating unit for cross seat heater showing coil mounted upon porcelain spindle, the terminals for making connections and the steel end.

The wire *offers a resistance to the current and as the current is forced through the wire, it heats the wire and raises the temperature of the surrounding air.*

The amount of power consumed by electric heaters naturally varies with the climatic conditions, but for cars ranging from 24 to 34 feet in length the power consumption for average and severe weather conditions varies from 5 to 7 *kw.* respectively, so that the electric heater loads on

both street railway and interurban systems compose a very large part of the total energy consumed. It is well known that on many well equipped electric railway systems, the amount of power consumed in heating and lighting the cars during very cold weather exceeds 20 per cent. of the power supplied to propel them. Both stove and hot water systems, however, possess several disadvantages. They occupy useful space, require special attention, and introduce dust, smoke and dirt into the car.

Construction of Heater Units.—Electric heater coils are made of special wire of such characteristics as are best for this purpose. The spindle supporting the coil consists of an iron

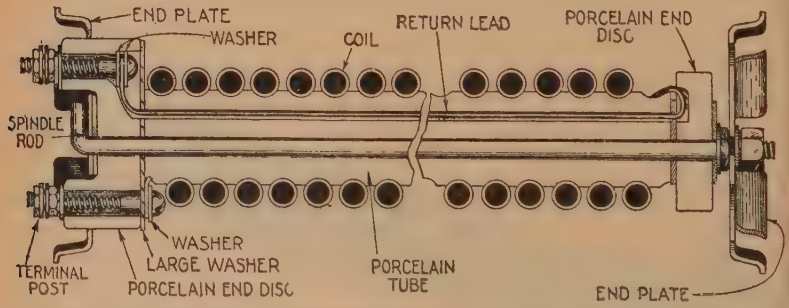


FIG. 6,486.—Sectional view of Consolidated heating unit for cross seat heater showing the return wire of the coil inside the porcelain spindle.

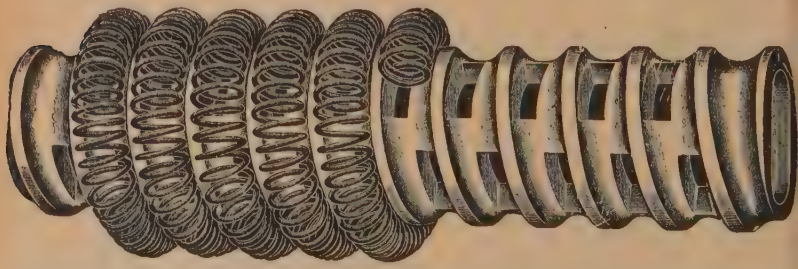
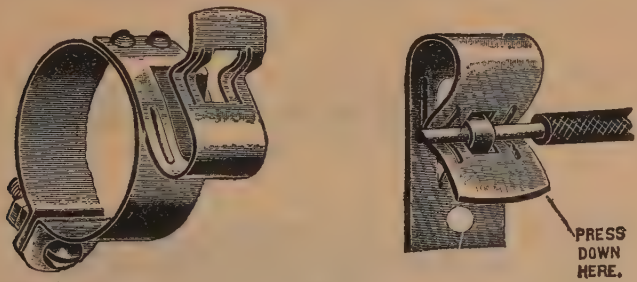


FIG. 6,487.—Ventilated porcelain core partially wound with resistance wire. The perforations in the porcelain core increase the radiating surface of the support, therefore the air passing through the supports and coils as well as around them give an efficiency not found where solid supports are employed.

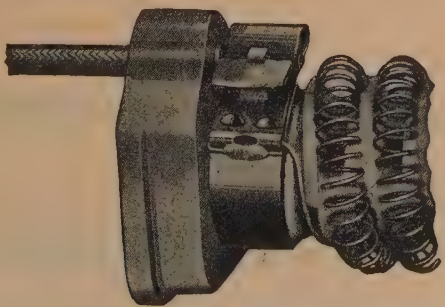
rod, on which are strung porcelain tubes which are so designed and fitted that a helical groove extends from end to end.

Eccentric bushings are placed on both ends of the rod and passed through the heater end plates. The wire for the heater coil is wound in a close spiral spring, between the ridges on the porcelain spindle under suitable tension, and the coils are thus properly supported at every point, preventing vibration. Crystallization of the wire with consequent fracture due to vibration is therefore avoided.

It is well known that wire expands with heat and contraction takes place again when the current is cut off.



IGS. 6,488 and 6,489.—Gold spring clip terminals. The object of the spring arrangement is to prevent vibration loosening the connections.



IG. 6,490.—Gold two-end connection showing application of spring clip. With spring clip terminals there is a direct connection from the resistance coil to the lead or service wire and no amount of vibration will loosen the connection to open circuit and cause arcing, as has happened with the binding post type.

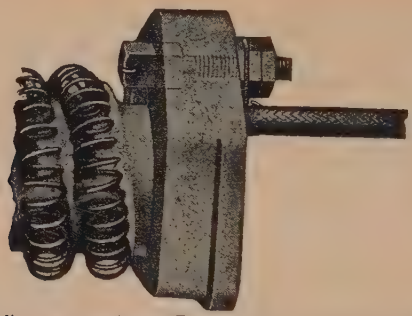


FIG. 6,491.—Gold binding post terminals. This manufacturer makes both kinds of terminal but recommends the use of spring clip terminals to prevent possibility of loosening by vibration.

FIGS. 6,492 to 6,497.—Gold service wire tips. These prevent the open circuiting of the wire a the terminals due to vibration at the point of contact; also eliminates frayed edges of the insu lation. In attaching type shown in figs. 6,492 to 6,494, the wire is sweated into the ferrule allowing about 1/8 inch of the bare wire to extend beyond the end of the tip, which end i dipped in solder, making a positive connection. Figs. 6,495 to 6,497 show the clamp type

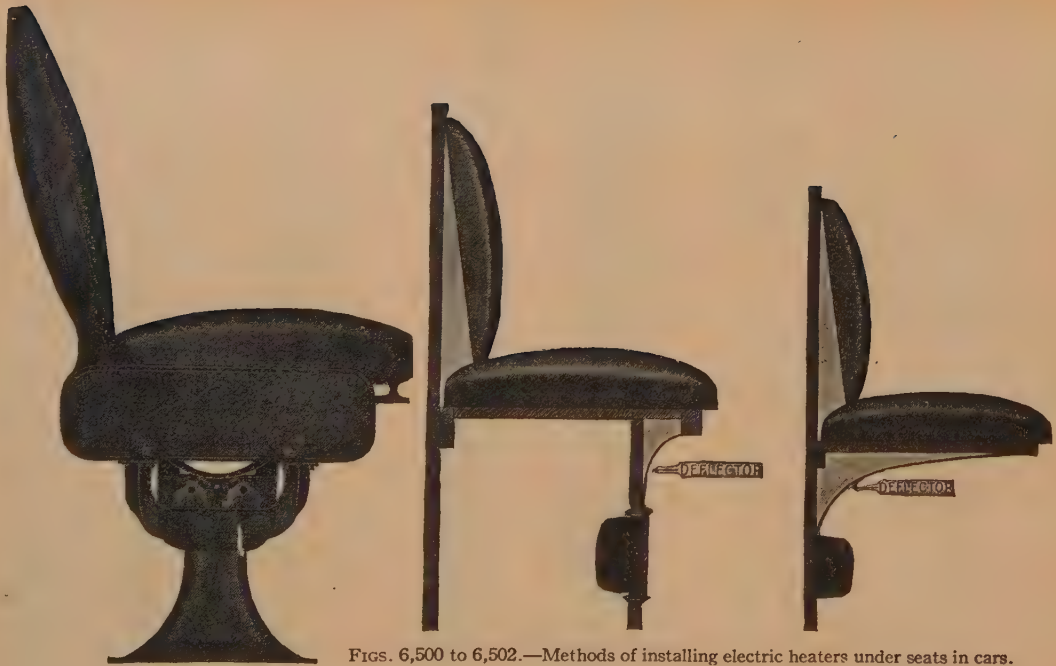
The spring of the coils not only holds them to the supporting insulator, but also takes up the expansion and contraction without disturbing the position of the coil on its support. Consequently, there is no danger of the wire breaking due to the strain of contraction as is the case where the resistance wire is wound straight around a bar or rod of insulation. This construction of the heating element allows the use of the maximum amount of wire in a given space and exposes every portion of the large surface presented, so that a large quantity of air comes freely into contact with it. The construction is shown in the accompanying illustrations.

Arrangement of Heating Circuits.—Heating equipments are usually arranged for three points of heat. The light coils are

FIG. 6,498.—Gold enclosed type heating element. The object of this construction is to conduct the heat away from the wire as quickly as possible. ***The parts are:*** A, outside sheath; B, micanite plate insulation, double thick; C, heating resistance, nickel chromium alloy; D, supporting strip; E, terminal washer; F, ferrule; G, ribbon lead connection.

FIG. 6,499.—Section of Gold element showing lead and method of attaching. Terminals are frequently weak points on heaters. In the construction here shown an extra wide lead of nickel is employed and several turns of the resistance wire are laced into it, providing a good contact without brazing or welding. This terminal will operate at temperatures in excess of that obtained in street car service.

NOTE.—***The surface temperature*** of the sheath of a car heater under normal rating is a little over 600 degrees Fahr. The minimum dehydration point of mica is from 1,200 degrees Fahr. (about the melting point of aluminum) to 1,800 degrees Fahr. A condition which never can be reached in car heating even though the heater should receive 100 % overload.

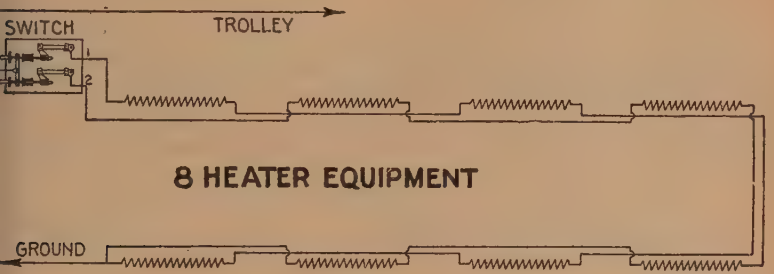


FIGS. 6,500 to 6,502.—Methods of installing electric heaters under seats in cars.

wired in series on each side of the car and connected to point 1 of the regulating switch. The heavy coils on each side are also wired in series and connected to point 2 of the regulating switch.

With No. 1 switch on and No. 2 off, one point of heat is obtained; with No. 2 on and No. 1 off, two points; and full heat is obtained with both switches on. Sometimes the heaters are made with all coils alike for two points of heat instead of three points. Where a single switch master is used ahead of the thermostatic control equipment, the heater fuses can either be contained within the safety switch or a separate fuse box can be used.

It is advisable to adhere to the arrangement providing for three different gradations of heat, where thermostatic control is used, as it makes possible the use of only one point of heat during rush hours, and thus the heater equipment is taking its minimum current at the time of the peak of the load.



IG. 6,503.—Connections of single unit heaters for seats running longitudinally in a car. Note staggered connections. Throwing in one switch sends current through one-half the number of heaters, but uniformly distributed.

Cross seat heaters are usually made with terminals at only ne end. The return wires are carried in passageways in the orcelain tubes.

Wire Used in Heater Elements.—For several years there ere a great many heaters constructed with resistance coils of alvanized iron wire, but there have been objections to the se of this wire because of its very high temperature co-efficient, s increased resistance under service and to its unreliable eriod of life, and it was found that the only point in its favor as the price, that made it possible for manufacturers using

this grade of wire to sell electric heaters at what seemed to be a ridiculous price as compared to electric heaters made with other grades of resistance wire.

Location of Heaters.—Figs. 6,500 to 6,502 show three methods of installing electric heaters in cars. They are placed under the seats as shown in the illustrations.

The deflector is for the purpose of preventing the heat lodging in a pocket under the seat. It is usually a plate of thin sheet steel fastened to the seat and curved so as to deflect the heat outward.

Methods of Connecting Heaters.—Depending upon the size of the car to be heated various numbers of heater units are

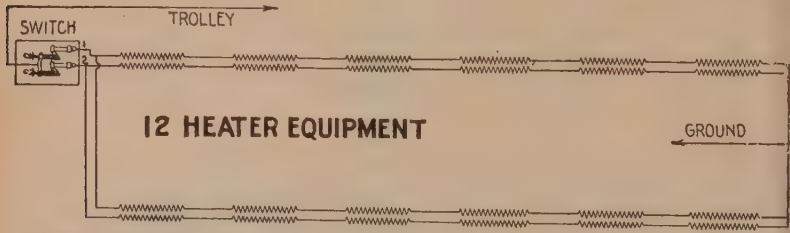


FIG. 6,504.—Connections of two unit heaters for seats running longitudinally in a car. Closing one switch sends current through one coil unit of each heater, closing both switches and full current is on.

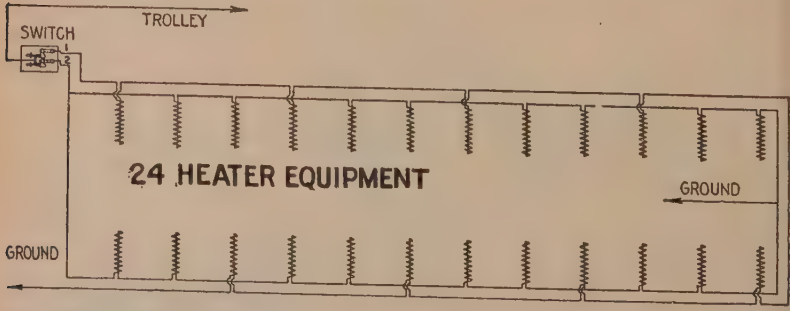


FIG. 6,505.—Diagram of connections for single unit cross seat car heaters.

used. The accompanying illustrations show installations ranging in size from 8 heater to 24 heater equipments.

Heat Control of Car Heaters.—In order to maintain the temperature at a desirable degree some means must be provided for controlling the heat given off by the heating elements. This may be done by

1. Manual control.
2. Automatic control.

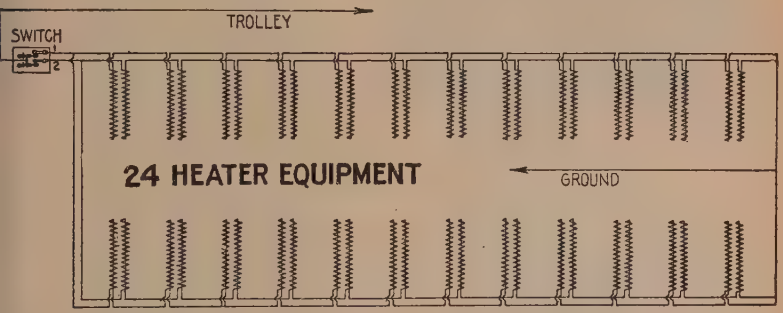


FIG. 6,506.—Diagram of connections for two unit cross seat car heaters.

Car Heating by Electricity

Test on Atlantic Avenue Railway, Brooklyn, N. Y.

Cars			Temperature F.		
Doors	Windows	Contents Cu. Ft.	Outside	Average in Car	Watts Consumed
2	12	850½	28	55	2,295
2	12	850½	7	39	2,325
2	12	808½	28	49	2,180
2	12	913½	35	52	2,745
4	16	1012	7	46	3,038
4	16	1012	28	54	3,160

FIG. 6.507.—Gold three degree reciprocating snap switch. Capacity 53 amperes; 600 volts.

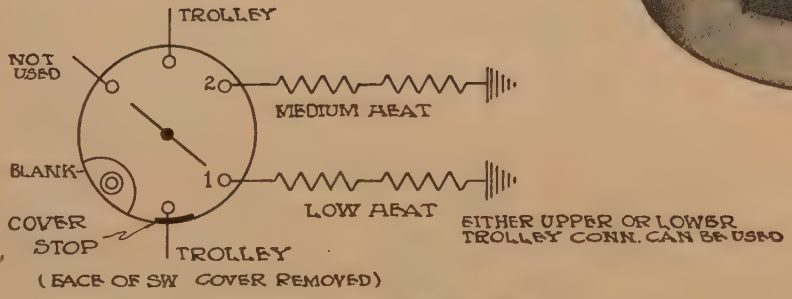
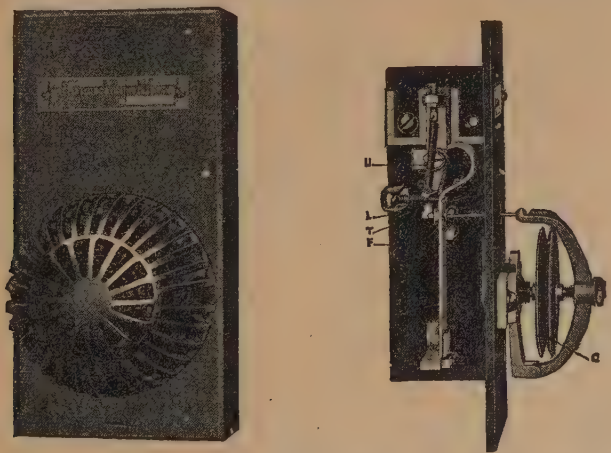


FIG. 6,508.—Wiring diagram showing hook up for Gold three degree reciprocating snap switch.

obtained respectively by means of:

1. Snap switch;
2. Thermostat.

Snap Switch Control.—Fig. 6,507 shows a type of snap switch which gives three degrees of heat, being shown in diagram in fig. 6,508. The switch can be snapped in either direction, therefore it is not necessary to pass from a low heat through a higher heat to open the circuit. The wiring diagram shows



FIGS. 6,509 and 6,510.—Gold thermostat. Fig. 6,509, outside view; fig. 6,510, case and element guard removed.

the face of switch with cover removed. Note indications are different from those shown on cover.

Thermostat Control.—By definition a thermostat is an automatic device by which *an electric circuit is closed when a given low temperature is reached, and opened when a given high temperature is reached.* Accordingly the purpose of a thermostat

of a type used with car heaters is *to automatically cut the current off the heating coils the moment a set car temperature is reached, and to cut it in when the temperature falls slightly below that point.*

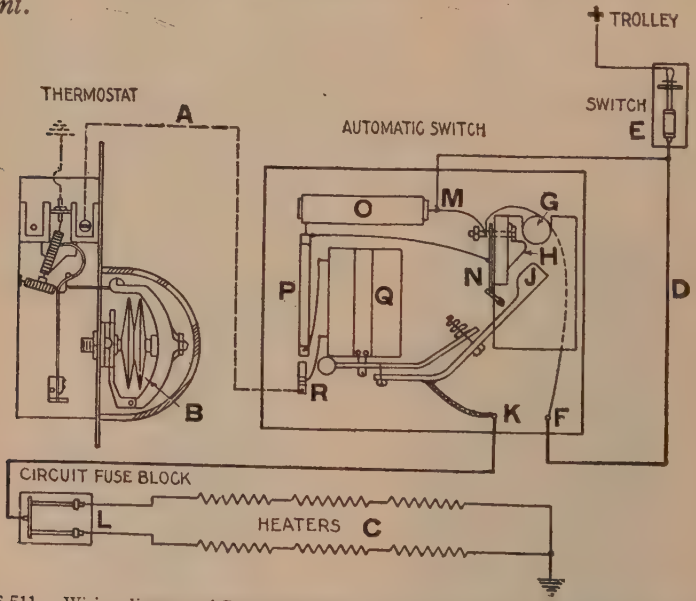
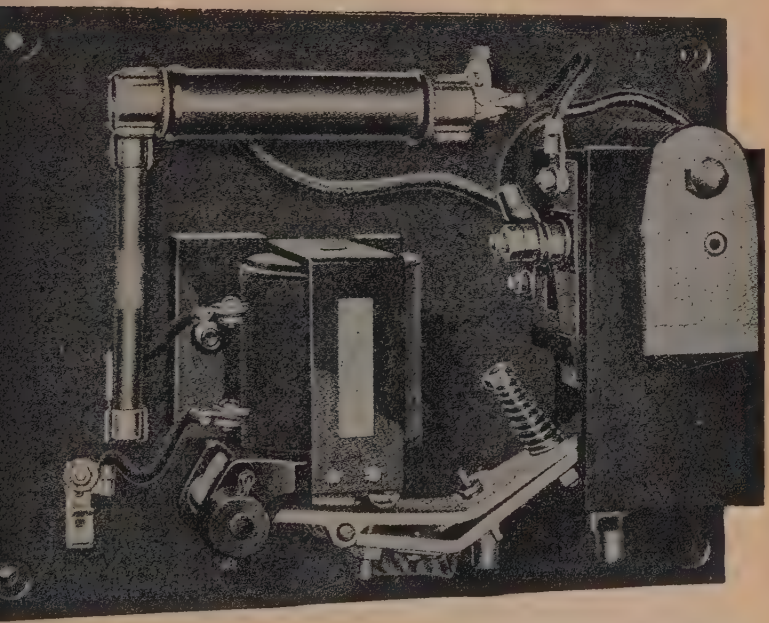


FIG. 6,511.—Wiring diagram of Gold thermostatic control. ***Method of operation:*** In the off position of the switch as shown, the thermostat having broken the circuit A, due to rise in temperature, thus expanding the diaphragm B, the electric heaters C, are of course cut out. When the diaphragm B, is contracted due to lowering of the temperature in the car a contact will be made in the thermostat, the current then passes from trolley through main switch E, through line D, to terminal F, on magnetic switch, through blow out coil G, to main contact H, through contactor J, to terminal K, through fuse block L, through heaters to ground. It will be noted that the positive pole of the line enters the magnetic switch at terminal F, and returns at terminal K. While it is preferable to wire the circuit as shown, no damage will result if the polarity be reversed and the switch will function equally as well. The thermostat receives its current from the main switch E, to terminal M, on magnetic switch and is shunted directly through fuse P, to main coil Q, to terminal R, through thermostat to ground. In the cut in position of the thermostat the current flowing directly through coil Q, which is energized draws up contactor arm J, closing the switch, using full line capacity of coil Q, in doing so. At N, is located a shunt switch, which when the switch is closing, opens the shunt around resistance O, placing this resistance in series with main coil Q, leaving just enough power in it to hold the switch closed, but reducing the voltage to such a degree that the arcing of the thermostat break is practically nil. With this method of wiring, the thermostat being grounded, it is impossible for any short circuit to occur at the thermostat.

In actual service the length of the cut out period is surprisingly long, aided partially by the action of the sun and again helped by the body heat from passengers at the crowded periods, allowing more current for the actual running of the cars when needed.

One construction of thermostat is shown in figs. 6,509 and ,510.



. 6,512.—Gold automatic switch. It is magnetic and performs the two fold function of pening and closing the circuit through which the heating coils are supplied, and of con- rolling the circuit from the thermostat so as to enable the thermostat to operate without parking or arcing.

The temperature sensitive element is the double diaphragm C, shown in fig. 6,510 containing a volatile liquid, the front wall transmitting its motion to lever arm F, lever arm F, operating a switching mechanism opening or closing the electric circuit. ***Example:*** as long as the diaphragm

is expanded by any temperature above the critical point for which the thermostat is set, the contact arm L, will remain in the off position. When the temperature falls, allowing the diaphragm to contract gradually, the contact arm L, will continue to remain in the off position until the continued recession of the diaphragm overcomes the tension of the spring U. When this occurs the contact arm L, jumps to the live contact by a quick and positive movement of over a quarter of an inch, cutting in the main heater switch. In other words, the thermostat performs the function of an ordinary single pole switch actuated by temperature changes. The thermostat, which is a delicate instrument, acts to operate the switch which controls the current supply to the heaters. The wiring diagram fig. 6,511, shows plainly the thermostat and switch with connections.

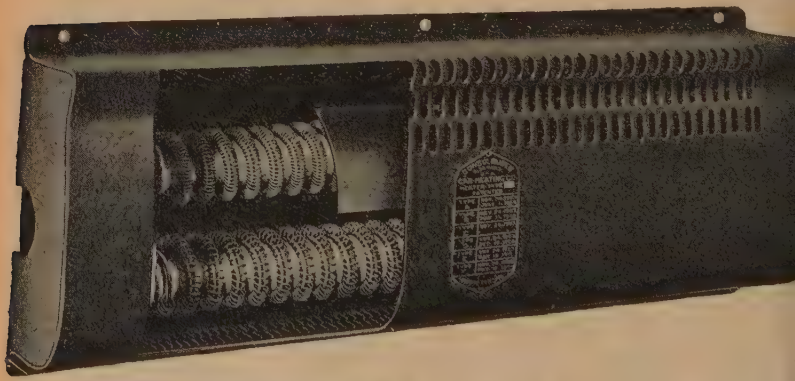


FIG. 6,513.—Consolidated double coil truss plank heater. ***It was designed*** for use on 1,200 to 1,800 volt circuit, as in the case of the single coil truss plank type. These heaters are used in a continuous row along the truss plank or side wall of the car. A deflector plate is provided which not only protects the coils against external injury, but also prevents the live parts of the heater being reached, so that it is impossible for passengers to receive a shock. The coils are secured to the spindles by means of an asbestos cord thus they cannot, even if they become broken, come in contact with the heater case. The back is made of sheet steel lined with asbestos and is brought forward at the top of the heater forming a deflector to project the heat out into the car.

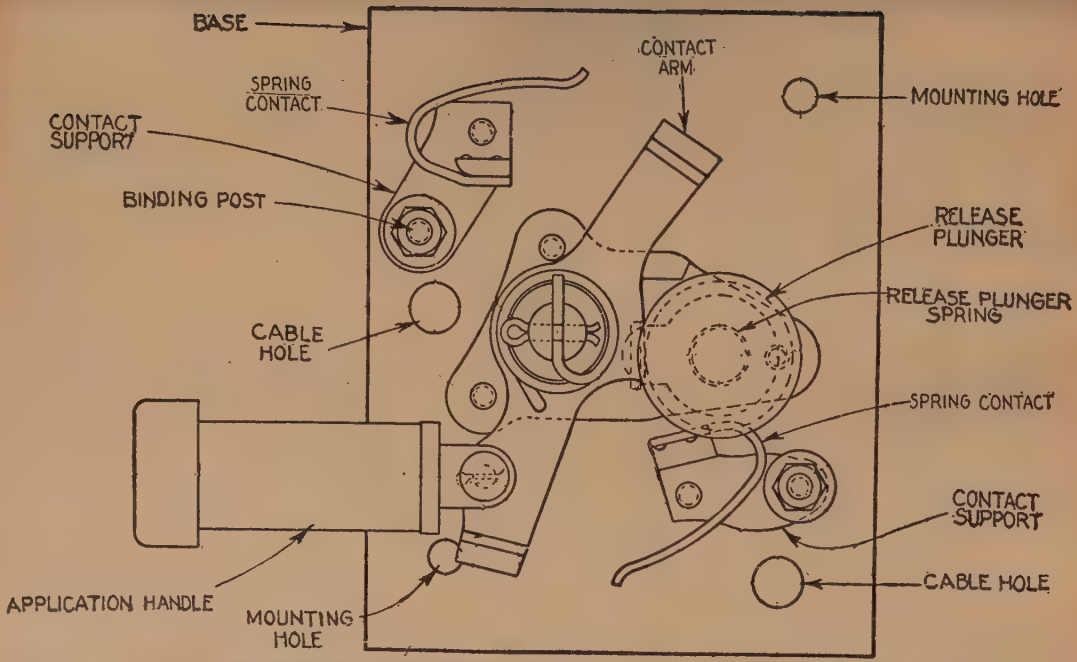


FIG. 6,514.—Gold door operated switch for vestibule heaters. This switch is used largely in vestibules of suburban, elevated and subway cars and is placed in a position so that when the motorman's cab is not in use and the door is folded back, it will press on the front plunger and cut the heat off the motorman's cab heater automatically. To obtain heat the left plunger is pushed in. Its use prevents the overheating of the small compartment when not in use.

TEST QUESTIONS

1. *How are electric cars usually heated?*
2. *How are the heating units made?*
3. *What kind of wire is used for the heating units?*
4. *How is the amount of power consumed by electric heaters varied?*
5. *What is the construction of a heater unit?*
6. *How many heating points are usually provided?*
7. *Draw diagrams showing arrangement of a heating circuit.*
8. *What two kinds of coil are used?*
9. *How is the heat controlled?*
10. *How are cross seat heaters usually made?*
11. *What are deflectors used for?*
12. *What is a thermostat?*
13. *How does a thermostat work?*
14. *Draw diagrams showing wiring of thermostats.*

CHAPTER 145

Railway Signals

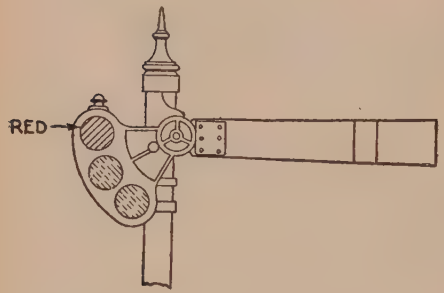
The author is indebted for able assistance in the preparation of Chapters 145 to 150 on the various systems of Railway Signaling to Mr. D. W. Van Gieson, Asst. Electrical Engineer (Railroad Signal Equipment), Board of Transportation, City of New York; one time Signal Engineer for New York State Transit Commission.

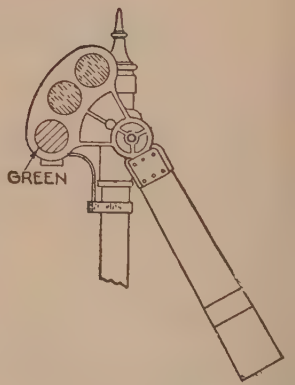
By definition a signal is *a means of conveying information to a train*—information necessary to the motorman or engineman in order that he may drive the train with safety, that is, properly directing its movement.

Signals may be classified:

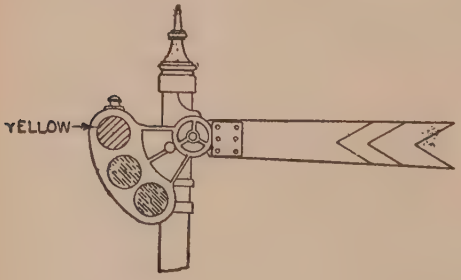
1. With respect to size, as:
   - *a*. High;
   - *b*. Dwarf.
2. With respect to the signal proper, as:
   - *a*. Semaphore;
   - *b*. Color light;
   - *c*. Position light;
   - *d*. Disc.
3. With respect to operation, as:
   - *a*. Automatic;
   - *b*. Semi-automatic;
   - *c*. Interlocking.
4. With respect to method of control. as:
   - *a*. Manual;

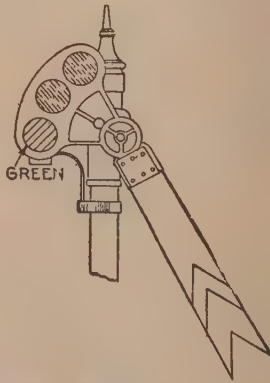
b. Mechanical;
c. Electric;
d. Electro-pneumatic.





FIGS. 6,515 and 6,516.—Two position *home* signal. Note shape of arm or "blade." Th front of it is usually painted red with a white stripe near its outer end and the back of i white with a black stripe near the end.



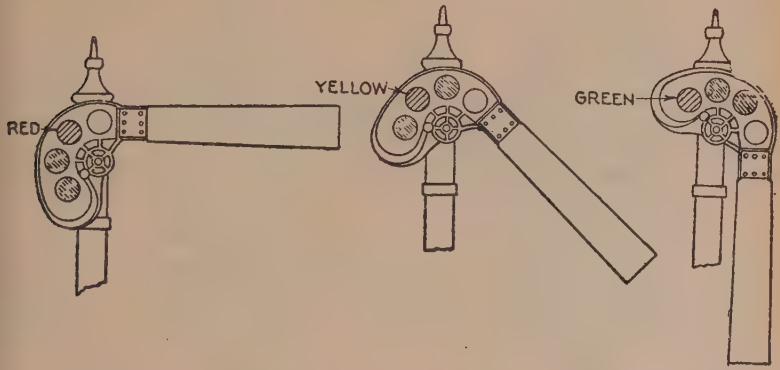


FIGS. 6,517 and 6,518.—Two position *distant* signal. The distant blade is made with a V shape or fish tail end. The front of it is generally painted yellow with a black stripe paralle with the end of the blade, or green with a white or red stripe. The back of the blade i painted white with a black stripe. A few roads that do not use this notation, paint th front of all blades yellow with a black stripe and the back black with or without a white stripe

5. With respect to location, as:

   a. Block {home / distant}
   b. Take siding, etc.

Semaphore Signals.—This type of signal is one in which *the day indications are given by the positions of a movable arm, and the night indications by colored lights.*



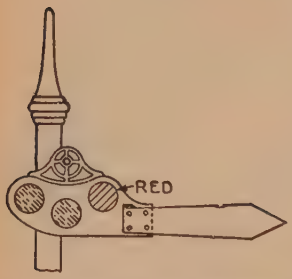
FIGS. 6,519 to 6,521.—Three position lower quadrant signal. The blades are made with square ends for interlocking purposes and with either square or pointed ends for block signaling. Where both square and pointed blades are used, the square end blades indicate stop and stay when the signal indicates stop.

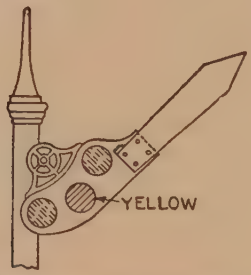
They may be classed as:

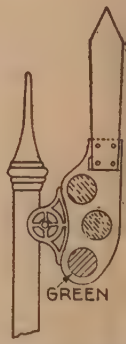
1. Two position:
   a. Home;
   b. Distant.
2. Three position:
   a. Upper quadrant;
   b. Lower quadrant.

Figs. 6,515 to 6,524 show the distinction between these two types.

Two position signal blades are often used in combination on the same signal post to give three indications. The home or top arm gives final authority to the engineman, the distant or lower arm merely repeating the indication of the home signal in advance; its function being purely cautionary.







FIGS. 6,522 to 6,524.—Three position upper quadrant signal. Where both square and pointed blades are used, the pointed end blades indicate stop and proceed at low speed when the signal indicates stop. Stop and stay is always the stop indication at interlocking plants. Three position blades have the front side painted red with a white stripe parallel with the end or yellow with a black stripe. The back side is painted white with a black stripe, or black with or without a white stripe.

Signal Indication.—Where lights are employed to give the indication, they are of two kinds:

a. Color—in Semaphore or Color Light Signals;
b. Position—in Position Light Signals.

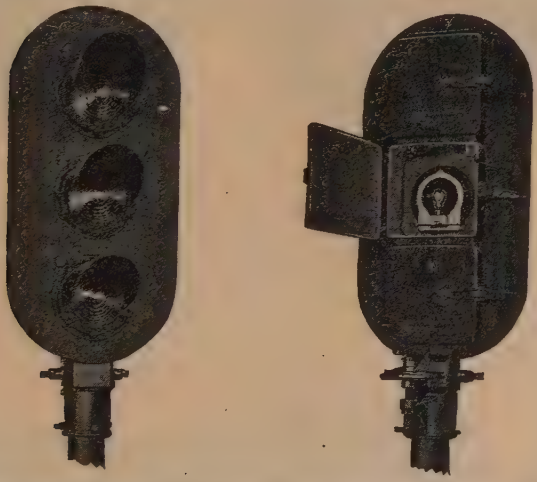
Color lights indicate by three colors, thus:

NOTE.—***The upper quadrant signal*** is the latest type of arm indication and possesses some advantages over lower quadrant movements, chief among which is the fact that the arm does not require a counterweight to place it in the stop position. This is of considerable importance in case of failure of signal operating mechanisms. Should sleet collect on the blade it would tend to pull the upper quadrant signal to the stop position and to hold the lower quadrant signal in the proceed position. There is little doubt, too, but that the blade giving the proceed indication in the upper quadrant can be seen farther by enginemen than one giving the same indication in the lower quadrant.

1. *Green*—proceed;
2. *Yellow*—slow down prepared to stop;
3. *Red*—stop.

Position lights indicate by their position, thus:

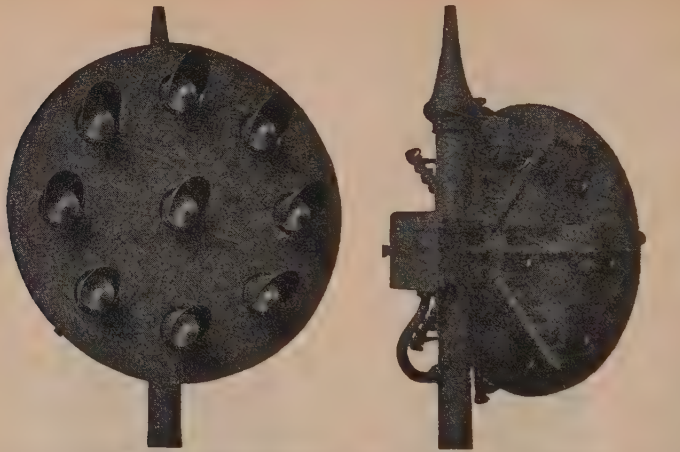
1. *Vertical*—proceed;
2. *Oblique*—slow down prepared to stop at the next signal;
3. *Horizontal*—stop.



FIGS. 6,525 and 6,526.—GRS three indication color light signal unit; front and back views. The unit construction of this signal reduces to a minimum the number of parts necessary for a railroad to carry in stock and simplifies the matter of adding or changing indications after installation. For instance, a change from a system employing two indication signals to a system employing three indication signals is made by simply bolting on another case containing an additional light unit.

Figs. 6,527 to 6,529 show construction of a position light signal.

Semaphore arms operate the same as position lights. An engineman may pass a distant signal set at caution, but he must be prepared to stop at the home signal set at stop. In the case of interlocking, he must stop and stay, while in some cases in block signaling he may proceed after the stop. Figs. 6,515 to 6,518 show the ordinary two position home and distant semaphore signals.



FIGS. 6,527 and 6,528.—GRS position light signal unit. This type is arranged to give four indications. ***It consists of*** nine lamps set around a cast iron hub bolted to a mast, and wired so that it can light three lamps in any one position. The lamps are 12 volt tungsten filament lamps and through the reflectors and lenses give a range of vision, in bright sunlight, of half to three quarters of a mile. The lamps are located on an 18 in. radius about the central lamp and the hoods and lenses project through a background attached to the pipe support by brackets. The wires leading to each lamp pass down the pipe supports to a central terminal box and from there, by flexible conduit down the mast to the source of current supply.

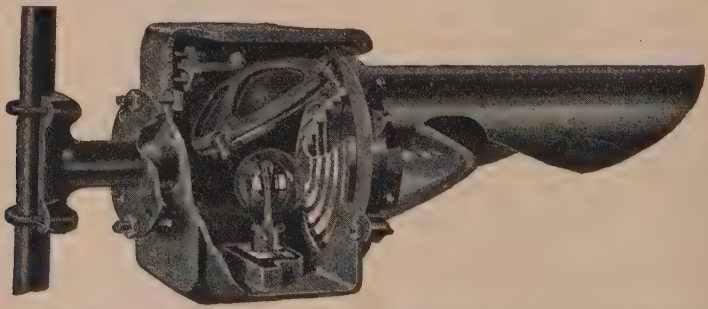


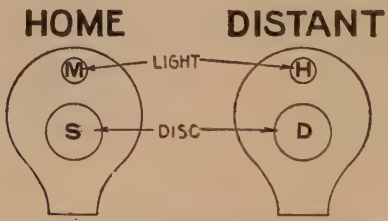
FIG. 6,529.—Position light signal lamp unit. ***It consists of*** a lamp, lamp receptacle, an inverted lens, a cover glass and a mirror reflector, contained in a cast iron case and a hood to keep reflection out. The lens is of clear glass with a focal length of 2¼ ins.; the cover glass is conical in shape, of amber tinted glass and has a frosted tip, the conical shape and frosted tip being to prevent reflection and sun glare, and the tinted glass gives a more penetrating beam for passing through fog. Further prevention of glare or reflection is procured by painting black the lower portion of the lens and having the lamp filament above the center of the lens. The mirror reflector adjusts for concentrating the beam.

Position-Light Signals		
Aspects High Signal		Indications
1		Proceed
2		Proceed prepared to stop at next signal
3		Proceed with caution prepared to stop short of train or obstruction
4		Stop
5		Stop and proceed as per rule
6	a b	Proceed prepared to pass next signal at medium speed
7	a b	Proceed at medium speed
8	a b	Proceed at restricted speed prepared to stop at next signal
9	a b	Proceed at low speed prepared to stop short of train or obstruction
Dwarf Signal		
10		Proceed at low speed
11		Proceed at low speed prepared to stop
12		Proceed at low speed prepared to stop short of train or obstruction
13		Stop
14		Take Siding

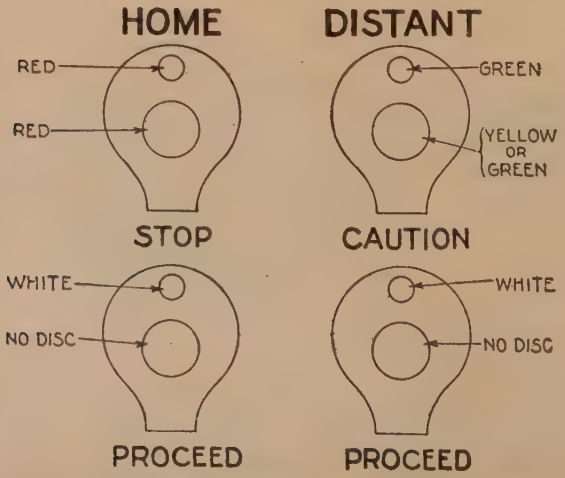
FIGS. 6,530 to 6,548.—Various position light signals and their meaning, giving interpretation for three light high signals and also for two light dwarf signals.

Disc Signals.—These are in use to some extent. By definition, a disc signal is one in which *the day indications are given by the color, or by the absence or presence of discs.*

Figs. 6,549 and 6,550 show essential features of disc signals. The indications are given in figs. 6,551 to 6,554.



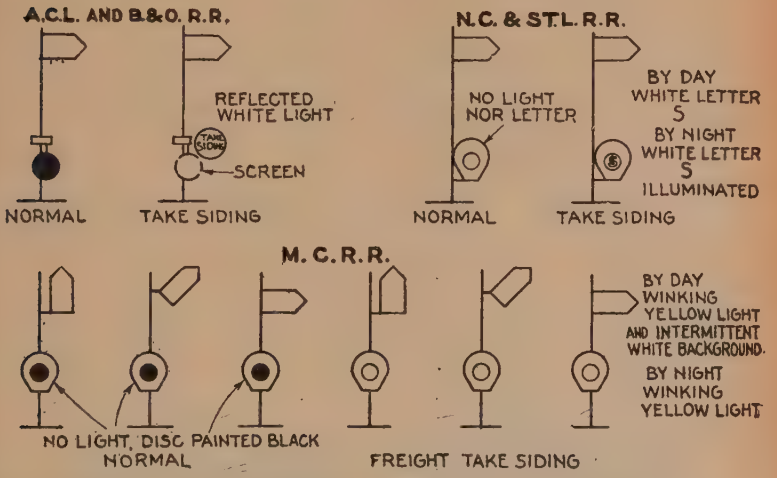
FIGS. 6,549 and 6,550.—Essential features of disc signals. *For day indication* there is a large circular opening S, in which a red disc can swing into view, the home signal has a red disc, and *for night indication*, there is a light M, just above the disc opening. The distant signal has an opening D, for a yellow or green disc and a light H, just above.



FIGS. 6,551 to 6,554.—Indications of disc signals.

Take Siding Signals.—The object of this class of signal is *to notify the engineer or motorman without the use of train orders, to take siding at non-interlocked switches, especially where located at some distance from operating towers.*

One form or another of the types of signal are used for this purpose, one example being a two blade signal in which the lower blade is operated at the oblique position in the upper quadrant and is marked with the words *take siding*, and illuminated at night. Various other methods are used to indicate siding orders.



FIGS. 6,555 to 6,564.—Take siding indicators as used by various railroads. 1.

Conclusions on Light Signals.—The following conclusions concerning the use of light signals are given in the 1917 volume of the Proceedings of the Railway Signal Association:

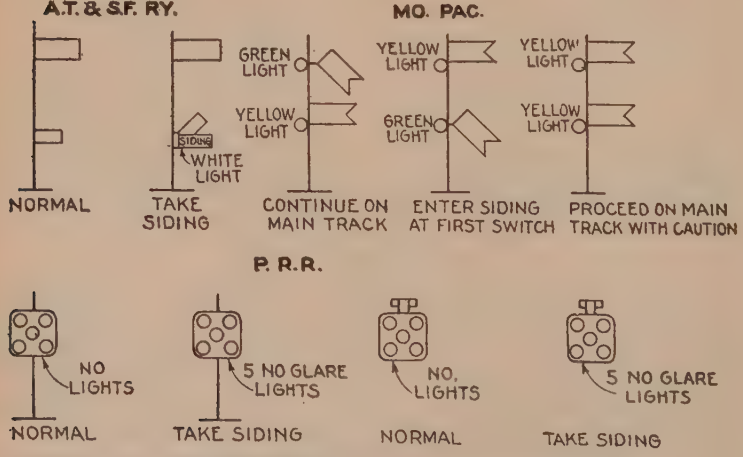
1. Colored and position light signals, for day and night use, by elimination of all moving parts except the control relays, reduce the number of failures.

2. Light signal aspects have greater visibility and range under adverse

weather and background conditions than the semaphore, while the close indications compare favorably.

3. Light signals give uniform indications at all times. Other types of signals give the indication by position in daylight, by color at night, and by both during transition periods. The various aspects of the position light signal are equal in intensity, range and visibility.

4. In general practice, the number of aspects of any one arm of a semaphore is limited to three. With the position light signal, four distinctive positions may be used, while the number of indications given by colored light signals is limited only by the colors available.



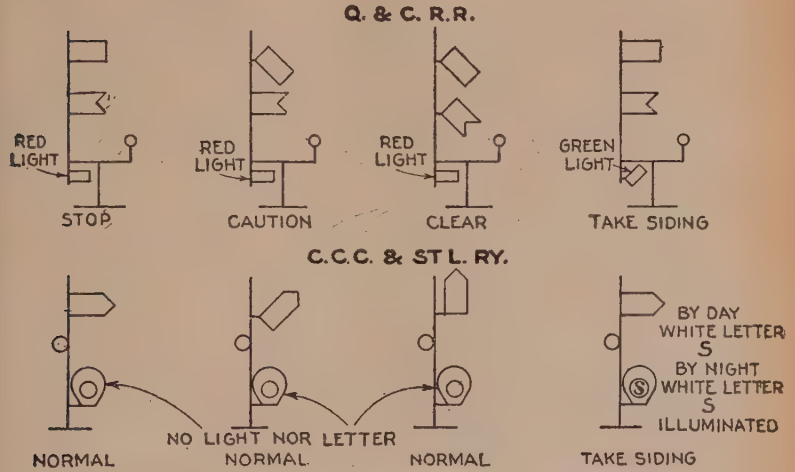
FIGS. 6,565 to 6,573.—Take siding indicators as used by various railroads. 2.

5. Where power is available, the cost of operating light signals is less than for operating motor signals.

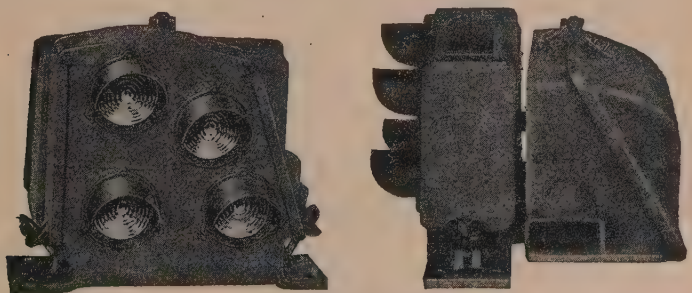
6. Current consumption under normal automatic signal conditions.—Position light signals: Four 5 watt lamps—20 watts. One colored light: 35 to 50 watts. For interlocking signals, consumption is increased depending upon the number of light displayed, but the ratio holds.

7. Cost of maintenance of light signals is considerably less than that of motor signals, and as the colored light signal has fewer lights to renew, it has an advantage in this respect over the position light signal.

8. The field for the economical use of light signals is limited, as noted above, to points where power is available. In this field, the light signals have advantages over other types. The position light signal can be installed at any location where clearance will permit the present standard semaphore to be erected. The colored light signal can be used in more restricted clearances.



FIGS. 6,574 to 6,581.—Take siding indicators as used by various railroads. 3.



FIGS. 6,582 and 6,583.—GRS position light dwarf signal unit. This type is designed for short range and its construction is different from the other types. The case containing the lamps is cast in one piece with a door on either side and is so arranged that a small cast iron relay box may be bolted on the back. The lamps are the type used in automobile head lights.

TEST QUESTIONS

1. *What is a railway signal?*
2. *Give classification of railway signals.*
3. *What is a semaphore signal?*
4. *Name several classes of semaphore signals.*
5. *Explain the difference between home and distant signals.*
6. *Is an upper quadrant signal more desirable than a lower quadrant?*
7. *What are the two kinds of signal indication where lights are employed?*
8. *How many colors are used in color light signals?*
9. *What do the different colors mean?*
10. *In position lights give the indications of the various positions.*
11. *What is the construction of a position light signal?*
12. *What is a disc signal?*
13. *Are disc signals used extensively?*
14. *What are the essential parts of disc signals?*
15. *How does a disc signal work?*
16. *What is the object of take siding signals?*
17. *What types of signals are used for take siding signals?*
18. *Give the conclusions on light signals according to the proceedings of the railway signal association.**

*NOTE.—The Railway Signal Association is no longer existent. It is now the Signal Section of the American Railway Association.

CHAPTER 146

Automatic Block Signals

The primary purpose of automatic block signals is the spacing of trains *a safe distance apart*, and the transmission of information to the engineman as to the presence of other trains which are about to interfere with his speed or movement.

There are some secondary advantages which are of much value, such as the detection of the position of switches, broken rails, etc. The important action of automatic signaling is that the passage of a train controls and actuates the operation of the signals, dispensing with the human agency, and providing for the protection of trains from following ones.

Block.—Automatic block signaling is accomplished by the placing of fixed signals along the trackway, each of which being so controlled as to indicate to the engineman the presence of an obstruction within a pre-determined section of trackway ahead of the signal. This section of trackway is called a *block*.

Home and Distant Signals.—A signal which gives indications for the block *immediately ahead* of the signal is called a *home signal*, that is, a home signal is located *at the entering end of the block for which it gives indication*. In fig. 6,584 A, is a home signal protecting block BC.

D is another signal which repeats signal A, by giving two distinctive indications dependent upon the indication of signal

A, and is known as a *caution* or *distant signal*. Signal D, may also be arranged to indicate the condition of block EB, as a home signal and thus become a combination home and distant signal.

A home signal shows the condition of the block directly in front of a moving train; and a distant signal the condition of the second block in front, or the block in the rear of the home block. An advance signal shows the condition of a block in conjunction with the home signal of that block. It is placed in advance of the home signal

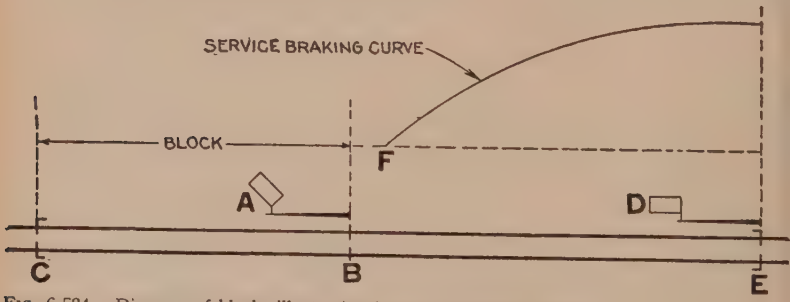


FIG. 6,584.—Diagram of block, illustrating home and distant signals.

It will be noted that the home signal *marks the* ***entrance*** *to the zone protected by the signal*, and, therefore, in case of an obstruction in this zone the signal may be of little or no value unless the train approaches it under full control.

The distant signal is designed *to afford advance information to enable the engineman to bring his train under control before reaching the home signal.*

It will be apparent that the distance between the home and distant signals should not be greatly in excess of the service braking distance for maximum speed, this in order to afford maximum facility and not require the engineman to carry the indication of the distant signal in his mind for a time after passing it before acting upon it.

Referring again to fig. 6,584, FE, is service braking distance for maximum speed and FB, is a reasonable margin of safety. It should be noted, however, that it is not by any means always practical to locate signals in accordance with these ideal principles. The distances, however, should

never be less than those just indicated and it will be apparent that the value of the distant signal decreases as these distances increase.

Single Track Signaling.—This differs essentially from double track signaling in that *it must afford protection for train movements in either direction*, whereas double track signaling presupposes all train movements to take place only in a predetermined direction on a given section of track.

Thus, in fig. 6,584 a train after accepting signal A, at clear may expect to find block BC, clear. However, if trains were operated in both directions as on single track, another train moving from left to right might pass C, after the first mentioned train had accepted signal A.

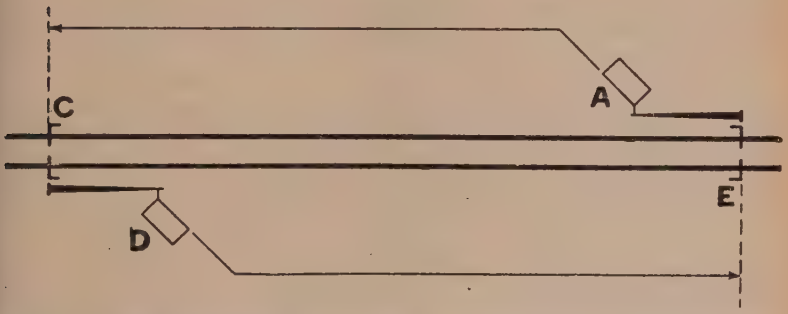


FIG. 6,585.—Signal arrangement which will afford certain protection for following movements, but not for opposing movements.

By providing another signal D, located at C, in fig. 6,585, to govern movements from left to right, and have signal A, control only to C, and signal D, to E, certain protection will be afforded for following movements, but is of little value to protect against opposing movements, as two opposing trains may pass signals A and D, respectively, at the same moment, both being clear, and meet in the middle of the block.

By providing an additional track circuit CE, and extending the control of signal A, to E, as in fig. 6,586, complete protection is afforded for opposing trains between B, and C, as a train moving from left to right will have caused signal A, to assume the stop position before it reaches signal D. It should be noted, however, that the extending of the control of signal A.

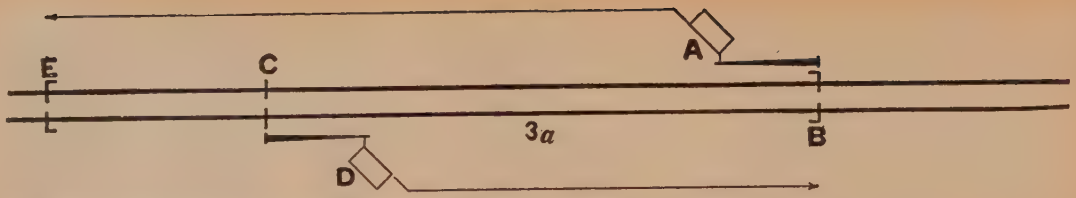


FIG. 6,586.—Signal arrangement with additional track circuit CE, and control extension of signal A, to E.

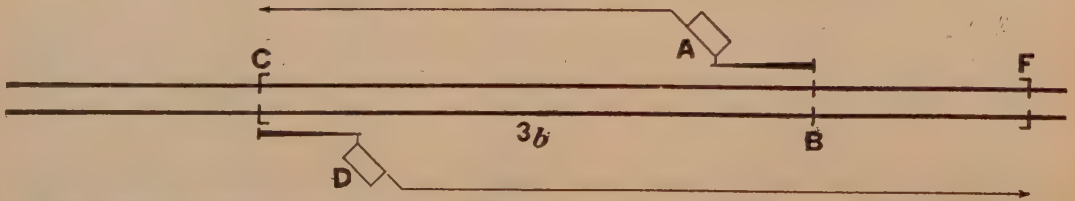


FIG. 6,587.—Signal arrangement giving protection for opposing movements by extending the control of signal D, to F.

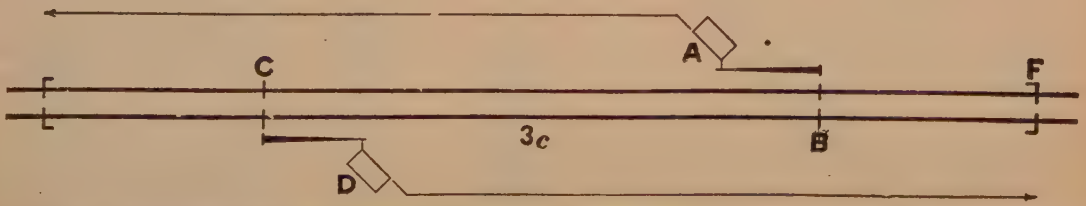


FIG. 6,588.—Signal arrangement giving complete protection by providing overlaps.

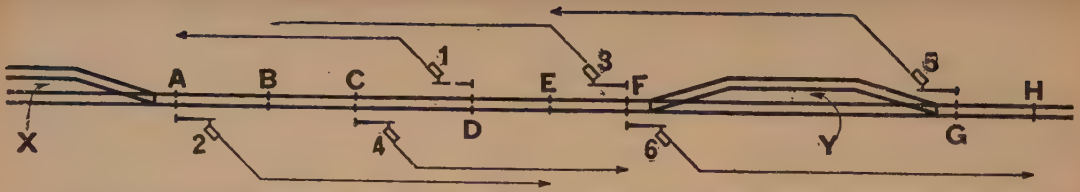


FIG. 6,589.—Early single track signal arrangements; X and Y, are adjacent passing sidings; signals 2 and 3, are starting or leaving signals; signals 1 and 4, are intermediate signals; signals 6 and 5, are siding signals.

may reduce facility as far as following movements are concerned, as the arrangement of signals may be such that a train moving from right to left need not have the protection of signal A, after it has passed C. This extension of the control of signal A, from C, to E, is called an *opposing overlap*.

The same degree of protection for opposing movements could be accomplished quite as well by extending the control of signal D, to F, as in fig. 6,587. The only difference is that preference would then be given to movements from right to left, while the arrangement shown in fig. 6,586, favors movements from left to right. Accordingly, complete protection is afforded by providing overlaps at both ends as shown in fig. 6,588. Earlier forms of single track signaling are based upon the principles just set forth and more or less literally applied.

Fig. 6,589 shows, as far as essential principles are concerned, the arrangement of signals and limits of control of the earlier forms of single track signaling. It will be seen that the arrangement affords complete protection in so far as it prevents one train colliding with another, either opposing or moving in same direction, so long as the signal indications are obeyed. There are, however, weaknesses in the system as follows:

1. Following trains are held apart farther than necessary. For instance, signal 2, must control to some point beyond signal 1, whereas from a standpoint of following protection this control need not go beyond signal 4.

2. With the controls as shown, after a train accepts signal 2, it will move to B, before placing signal 3, to the stop position. Meanwhile an opposing train can accept signal 3. Of course these trains will be held apart by signals 1 and 4, but delay and inconvenience will result. It is to be admitted that this condition can only exist as a result of error in, or disobedience to orders, but it is also good practice to make the signals prevent such a condition so far as it can be done without sacrificing other facility or protection.

3. Distant signals become of questionable value, as a train may get a clear distant indication and find the home signal at stop due to an opposing train having in the interim entered the block of the home signal. For example, if a distant signal be provided for signal 6, a train may find this signal clear and find signal 6, at stop due to an opposing train having entered the block of signal 6. Furthermore, it will be seen that this is not an unusual

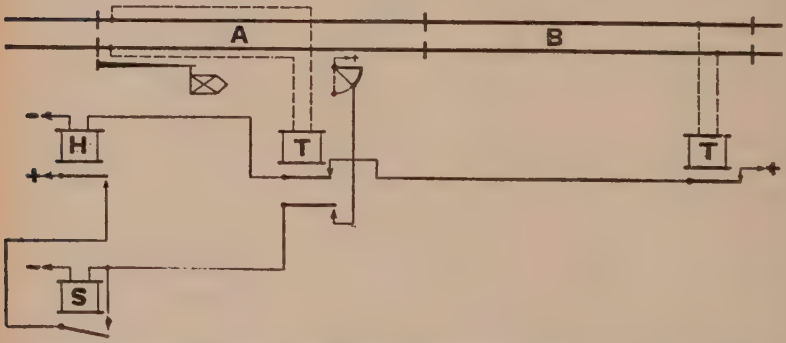


FIG. 6,590.—Absolute permissive block system circuits showing variable control by *stick relay*. H, is the control relay for the signal and is controlled by two track relays A, and B. S, is the stick relay. It will be noted that the pick up of the stick relay is through a back contact of relay of track circuit A, and a contact operated by the signal, which is closed say from 45° to 90°. The holding circuit for the stick relay is through a front contact of the stick relay itself, and a back contact of the signal control relay. It will therefore be seen that when a train passes the signal moving from left to right, it first drops relay for track circuit A, and the signal being clear, the pick up circuit is thus made. That is to say, the signal will remain clear for a sufficient length of time to pick up the stick relay and the stick relay will remain picked up as long as the signal control relay remains de-energized. It should be noted that the contact operated by the signal can be closed at any part of the stroke except that it must be open when the signal is at stop and must be closed for a long enough period after passing below the 45° position to allow sufficient time for the stick relay to pick up. It will furthermore be seen that a train moving from right to left will not pick up the stick relay, as the de-energization of track circuit B, will have caused the signal to assume the stop position before the train has reached track circuit A. Therefore, the pickup circuit will not have been made at any time.

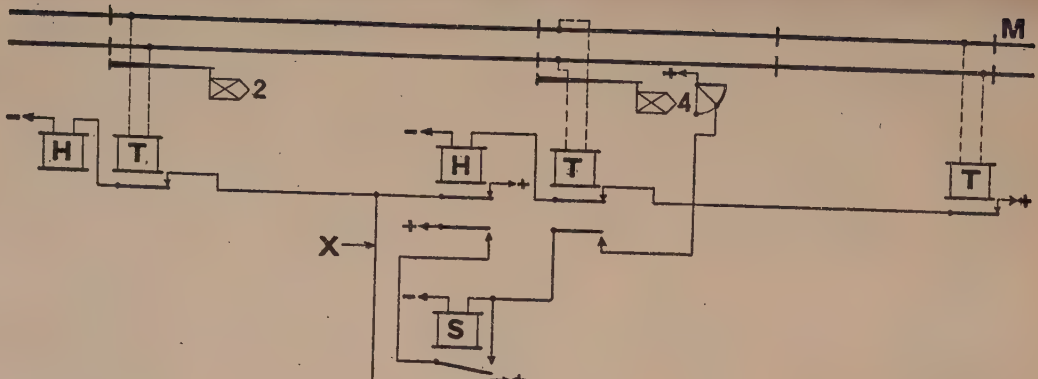


FIG. 6,591.—Absolute permissive block system circuits showing essential means of detecting traffic direction on single tracks. ***In the diagram,*** signal 4, controls to M. Also if wire X, be disregarded signal 2, will control to M, as the control for signal 2, is broken through the control relay for signal 4. It will be seen that wire X, feeds energy to the control wire for signal 2, when the stick relay is picked up even though the control relay for signal 4, is de-energized. Therefore, a train moving from left to right will allow signal 2, to clear as soon as it passes signal 4, as the stick relay will be picked up as long as the train is in the block of signal 4. However, in the case of a train moving from right to left both signals 2 and 4, will be caused to assume the stop position as soon as the train passes M, as the stick relay will not pick up for this movement. In other words, signal 2, has an overlap for opposing movements but not for following.

condition, but on the contrary, it is entirely regular when two opposing trains are approaching a siding for a meet and both are on time.

For a long time a considerable number of signal engineers questioned the advisability of automatic block signals on single track on account of these seemingly inherent shortcomings, and in order to overcome these defects a system known as the *absolute permissive block system* has been developed.

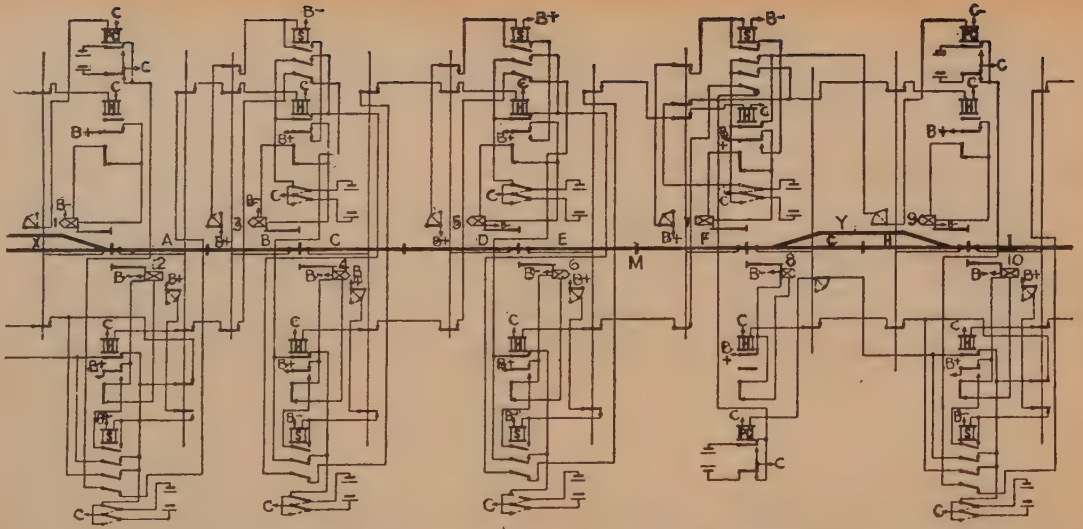


FIG. 6,592.—Absolute permissive block system circuit showing the arrangement of signals and circuits as usually employed. ***The diagram shows*** two simple sidings X, and Y, with the usual two signals at each end and with two pairs of intermediate signals. In this case both pairs of intermediate signals are shown opposite. However, the general scheme is not affected in the case of staggered intermediate signals. It will be seen that the control wire for signal 2, is carried forward and broken through front contacts of the control and stick relays at signal 4. Likewise the control of signal 4, is carried forward to signal 6. Signal 6, however, only controls to signal 8, or the end of the signal track block. Signals 7, 5 and 3, are controlled exactly the same as 2, 4 and 6. Therefore, a train moving from right to left upon passing signal 7, will cause signals 6, 4 and 2, to assume the stop position, as the stick relays at signals 4 and 6, will be de-energized. Thus, a long overlap is provided for opposing movements, to the next siding in each instance, and this is not objectionable in the case of following movements, as these overlaps are then cut off by the stick relays in a manner already explained. Furthermore, the siding signals have a varying control depending upon direction. For example, signal 9, controls to M, for opposing movements, but only to signal 7, for following. The net result is complete overlap protection from siding to siding for opposing movements, and signal to signal protection for following movements the same as on double track.

Absolute Permissive Block System.—This system is designed to afford: 1, Full overlap protection for opposing movements, and 2, Protection same as on double track for following movements.

This involves that the extent of control of a signal must be variable and depend upon the direction of traffic. For instance, in fig. 6,589, signal 2, must control at least to some point E, for opposing movements and preferably to signal 3, as the chances of opposing trains entering the single track between sidings X and Y, are thereby greatly reduced. Signal 2, however, for following movements needs only control to signal 4. The means for providing this variable control is an ingeniously arranged stick relay as shown in fig. 6,590. Thus, according to fig. 6,590, means are provided for detecting the direction of traffic, that is, a relay energized during the time a train is moving through a block in one direction and de-energized during the same period if moving in the other direction. An essential way, in which this means of detecting traffic direction applied to single track signaling, is shown in fig. 6,591.

The application of the principle shown in fig. 6,591, to actual single track conditions is shown in fig. 6,592.

It should be noted that in practice general modifications are made due to local conditions and general standards. For instance, siding arrangements and their relative positions vary; some roads want polar line circuits, while others insist upon neutral; some employ 3 position signaling, others 2 position; some use one battery for line and motor control, others use separate batteries. While the system as illustrated in fig. 6,592 is essentially the same as first conceived, it has fulfilled all the requirements.

NOTE.—Early in the development of the absolute permissive block system, certain protective features not heretofore described were recognized as necessary or advisable. For instance, the question was asked as to the result of a stick relay remained picked up as might be the case if the control relay failed to pick up after the train had cleared its block. For example, if stick relay at signal 4 (fig. 6,592) be improperly picked up for any cause, signal 2, would then be at 45° even with an opposing train between signals 4 and 7. To protect against such a condition it will be noted that for instance the control for signal 5, is broken through a back contact of the stick relay for signal 4. Therefore, after a train has passed signal 4, moving from left to right the stick relay for signal 4, must again drop before either signals 5 or 7 can clear for an opposing movement. A careful study of the whole arrangement will disclose the fact that after a train movement has established traffic in one direction, the signals will not permit a reversal of traffic until the stick relays have been restored to normal or de-energized position.*

*NOTE.—In order to overcome the difficulties in connection with the distant signal, before referred to, it will be noted that the 90° position of signals governing the approach to sidings

D. C. Track Circuits.—The track circuit is the fundamental basis upon which the automatic signal has been developed. The simplest form of track circuit is the *d.c.* battery fed circuit as used on steam roads. This type of track circuit is shown in fig. 6,593.

Normally Closed and Normally Open Track Circuits.—The track circuit described in figs. 6,593 and 6,594 is of the normally

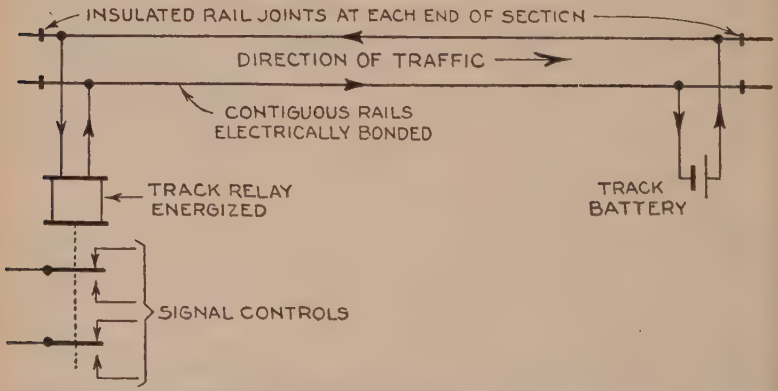


FIG. 6,593.—*D.C.* battery fed track circuit. The track relay is usually connected across the rails at the entering end of the section and the battery is connected across the rails at the leaving end, the rails forming part of the completed circuit. Contiguous rails of each section of track are electrically connected to each other with bond wires, and insulated rail joints are placed in both rails at each end of the section, insulating one section from the adjacent sections. The path of the current can be traced along the direction shown by arrows from the positive terminal of battery along one set of rails to the relay, passing through its coils, and returning along the other set of rails to the negative terminal of the battery.

NOTE.—*Continued.*

has been given a varying control depending upon direction. For instance, the 90° position of signal 6, depends always upon the position of signal 8, and upon signal 10, for opposing movements only. In other words, signal 6, will assume the 45°, as will also signal 8, as soon as a train, moving from right to left, leaves the siding next to the right of siding Y. However, this distant indication for following movements is the same as on double track. The great value o this feature will be apparent. The advantages are: 1. It prevents a condition in which a train passes a full clear signal and finds the next signal at stop and occupied by an opposing train. 2. It insures that a train will always get a caution signai when approaching a meeting point unless the opposing train has not left the next adjacent passing siding.

closed type since the circuit is complete through the relay when the track section is normal and unoccupied. The normally open type of track circuit is shown in fig. 6,595.

Basic Principle of Signaling.—Signal apparatus, controlling circuits, etc., must be so designed, installed and maintained that, so far as may be fairly practicable, *the derangement of any*

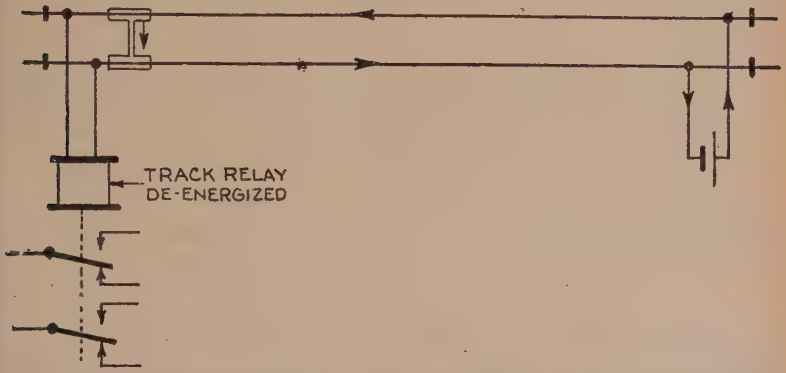


FIG. 6,594.—Diagram showing effect of a train in the block. This causes the current to be shunted through the low resistance return path offered by the pair, or pairs of wheels and axles of the train, and consequently there is little or no current flowing through the track relay. The relay is, therefore, de-energized during a train's occupancy of the section and the relay contacts are changed in position. Thus it is that the response of track relay to train movement through a section provides the means of automatically setting up circuit control conditions to supply or remove energy for any operated function, whether it be a line relay, signal light, signal motor, or other device. Thus is the means provided to control a signal to assume an aspect of color or position in the rear of a train which will indicate stop, or other less restrictive indication.

part, or failure of a part to perform its function, will react safely in its effect upon train movement.

This means that operations must rather be prevented at a time when they would be safe, than left free, by derangement, to be performed under unsafe conditions.

End Fed and Center Fed Track Circuits.—The track circuits shown in figs. 6,593 to 6,595, are of the end fed type. Fig. 6,596

shows a center fed track circuit where the track battery is located at the center of the block, and feeds both ways to relays at both ends. The presence of a train in this section de-energizes both relays.

While this type of track circuit requires the use of two track relays, it is employed to advantage on very long track sections where the use of end

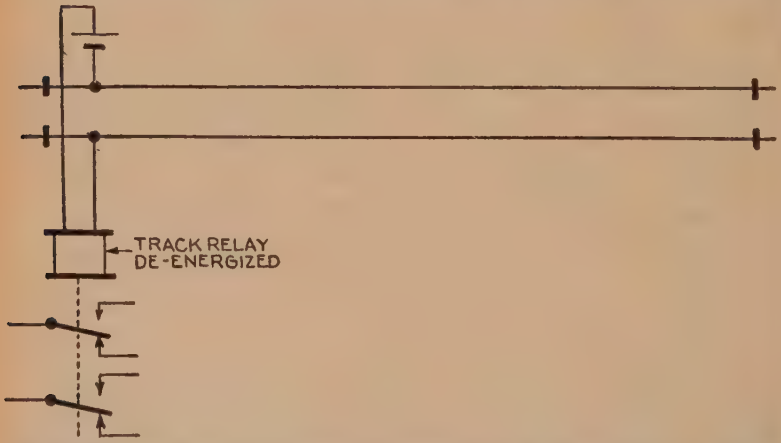


FIG. 6,595.—Normally open type, battery fed track circuit. In this type of circuit the presence of a train in the block completes the circuit through the track relay. While this type of circuit is economical in that it saves battery current, it has serious disadvantages and is used to a very limited extent. Its principal disadvantage is the uncertainty of the relay picking up. Any failures of the apparatus, such as a broken rail, exhaustion or breakage of the battery cell, or the breakage of any of the wires will render the apparatus inoperative. The detection of failures is not provided since the apparatus is maintained normal in the event of failure.

fed circuits would require a higher voltage to overcome the greater resistance of the long rail sections forming part of the circuit.

A. C. Track Circuits.—Alternating current track circuits and signaling are gradually superseding other systems. Being immune from the dangerous effect of extraneous direct current; being capable of selection between signaling current and the

a.c. or *d.c.* propulsion current and giving more economical operation where *a.c.* power is obtainable, the *a.c.* track circuit is being used almost universally on electrified railroads.

Where the traction current is *a.c.* the signaling current is of a different frequency. The principle of *a.c.* track circuits is similar to that of *d.c.* circuits. The high tension signal voltage is stepped down from the signal mains by means of transformers to the required working pressure for the track circuits. *A.c.* track circuits for use on electric lines are divided into two classes, viz. single rail and double rail.

FIG. 6,596.—Center fed track circuit.

Single Rail Track Circuit.—When one rail provides sufficient conductivity for the negative return traction current, and where complete broken rail protection is not a requirement, the single rail track circuit is employed.

On account of its comparative simplicity, it is also used in yards or other complicated sections of special track work where the use of impedance bonds required in connection with double rail track circuits would be difficult of installation. Fig. 6,597 shows a typical *a.c.* track circuit.

Double Rail A.C. Track Circuit.—Where both rails must be retained to provide sufficient conductivity for the negative return traction current, or where broken rail protection is a requisite, the double rail track circuit must be employed. In this type of track circuit both rails are also used for the signaling current. A typical double rail *a.c.* track circuit is shown in fig. 6,598.

Impedance Bond.—This usually consists of a laminated iron structure in which is placed a coil of a few turns of heavy copper conductor.

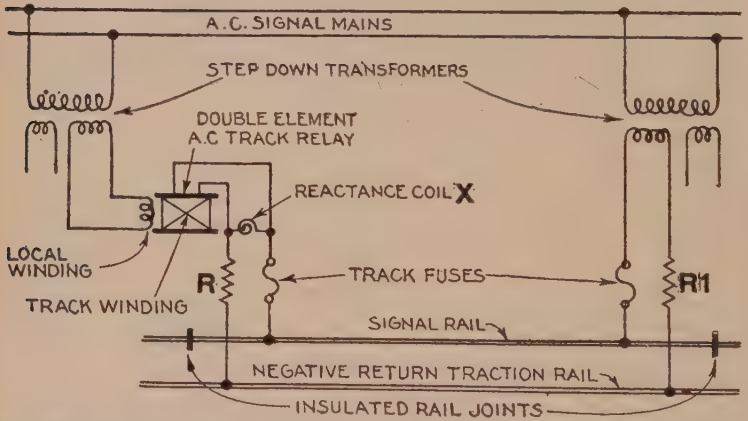


FIG. 6,597.—Single rail *a.c.* track circuit. ***In this type*** of track circuit only one rail, the signal rail, is insulated at either end of the block. The other rail is used jointly for the signal current and the traction current. The double element relay shown in the diagram permits of a low voltage being employed for the track circuit, which is advantageous. This voltage must be low or the circuit becomes supersensitive to leakage variation between rails. The reactance coil X, is shunted across the track relay where traction current is *d.c.* to limit or by-pass the *d.c.* which would otherwise flow through the relay, as inter-rail voltage exists on single rail circuits. The reactance coil is designed to impede the flow of *a.c.* and to offer low ohmic resistance to the flow of *d.c.* The resistance R, also limits the flow of *d.c.* to relay. The resistance R1, limits the *d.c.* to the transformer and also limits the flow of short circuited *a.c.* from the transformer when a train is in the block. While the *a.c.* track relay will not respond to *d.c.* its efficiency is lowered by the flow of *d.c.* through its windings.

NOTE.—***Another point*** in connection with *a.c.* track circuits is that adjacent track sections are always fed with alternate polarities from the transformers. This provides for the detection of broken down insulated joints. With the type of double element track relay shown, that is with one winding fed from the track and the other winding fed from a local source of energy, the relay will operate in one direction with a given polarity, and will operate in the other direction if the polarity be reversed. Therefore, if either of the insulated joints should break down, the energy from the transformer passing across the broken down insulation would cause the relay of the adjacent track circuit to open positively thus setting the proper signals at stop and caution. With relays which take all their energy from the track this will not hold true.

The coil and laminations are enclosed in a waterproof iron case. The ends of the coil and a tap from the middle of the coil are brought out through the sides of the case and are provided with suitable terminals so that connections can be made to the rails and between the bonds with heavy copper cable.

Impedance bonds are located in the middle of the track between the traffic rails and are set down in the ballast between the ties so that the cover of the

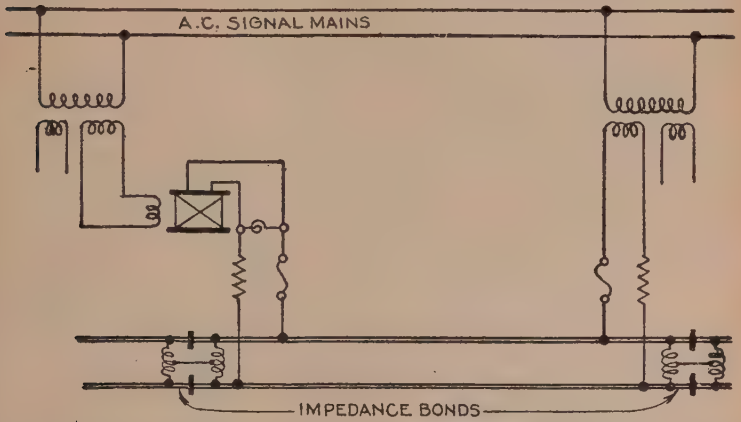


FIG. 6,598.—Double rail *a.c.* track circuit. This differs from the single rail track circuit in that both rails are insulated at either end of the block and that impedance bonds are used. The function of the impedance bond is to keep the rails electrically continuous for the traction currents and at the same time electrically separated for the signaling current. It can be seen from the method of connection of these bonds to the rails that if it were not for the impeding or choking effect of the bond, a short circuit between the rails would ensue. ***In operation*** direct currents flowing into a bond from the two rails toward the middle point of the bond are in opposite directions and the ampere turns due to each half of the coil tend to neutralize each other so that when the same amount of current flows in the bond from each rail the resultant ampere turns are zero. The *d.c.* traction current, therefore has no magnetic effect on the bond unless more current flows in one rail than in the other. in which case it would have a magnetizing tendency, which if too great, would lower the reactance of the bond, changing its resistance to alternating currents, and lowering the voltage available for the operation of the track relay. As this difference of current in the rails, called unbalancing, is likely to occur due to poor rail bonding connections in either rail, the impedance bonds are designed with an air gap in the magnetic circuit which makes them less sensitive to unbalancing. The reason for the impedance bond's high resistance to the flow of *a.c.* is as follows: Whenever a current is caused to flow through a coil, especially when wound on an iron core, a strong magnetic field is produced which in becoming established produces a counter electromotive force which opposes the impressed voltage and delays the building up of the current. If now, the current be caused to alternate many times a second, it will never be permitted to build up to its full value, that is, as represented by a constant voltage divided by the ohmic resistance.

case is just above the top of the ties. The method of connecting impedance bonds and their operation is shown in figs. 6,598 to 6,600.

D. C. Track Relays.—These instruments are usually of the tractive type or motor type. Figs. 6,601 and 6,602 illustrate the two types of relay.

A. C. Track Relays.—There are three important types of *a.c.* track relays known as

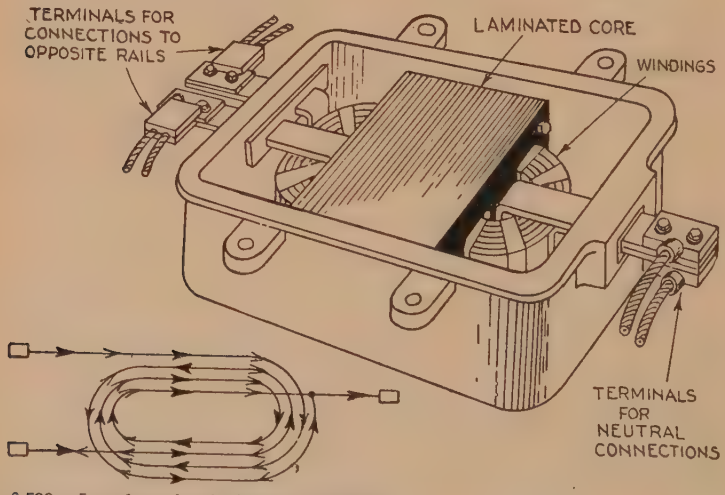


FIG. 6,599.—Impedance bond with cover removed.

FIG. 6,600.—Diagram of current in impedance bond. Heavy arrows indicate parallel paths of *d.c.* Light arrows indicate impeded *a.c.*

1. Galvanometer relay;
   - *a*. Ironless.
   - *b*. Iron.
2. Vane relay;
   - *a*. Single element.
   - *b*. Double element.
3. Polyphase relay.

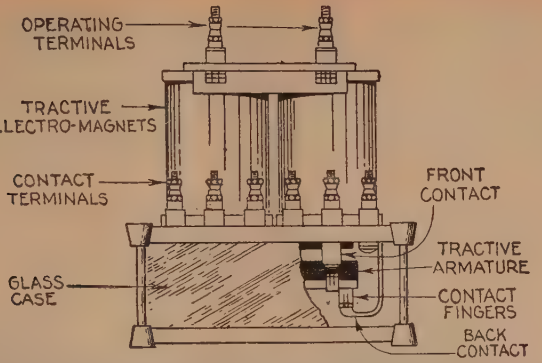


FIG. 6,601.—*D.c.* tractive type track relay. ***The operation*** for the changing of contact positions depends upon the principle of electro-magnetic attraction. The electro-magnets when energized attract an armature which actuates the mechanical movement of the relay contacts, picking them up. The de-energization of the relay allows the armature and contacts to drop away by gravity.

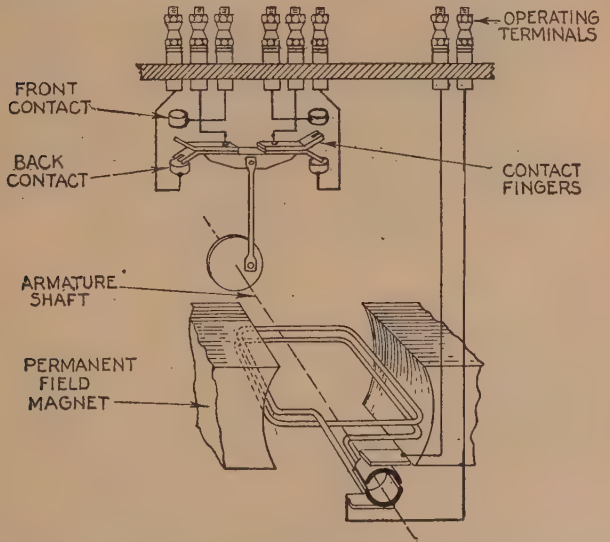


FIG. 6,602.—*D.c.* motor type track relay. ***The operating mechanism*** usually consists of a small *d.c.* motor having powerful permanent magnet fields. The contacts are moved from the de-energized to the energized position by rotary motion of the motor armature, the movement of which is transmitted to the contacts by suitable link arrangement.

Galvanometer Relay.—The ironless galvanometer relay is of the two element type, having *two separate windings and operating as its name implies, on the galvanometer principle.* Fig. 6,603 illustrates this relay.

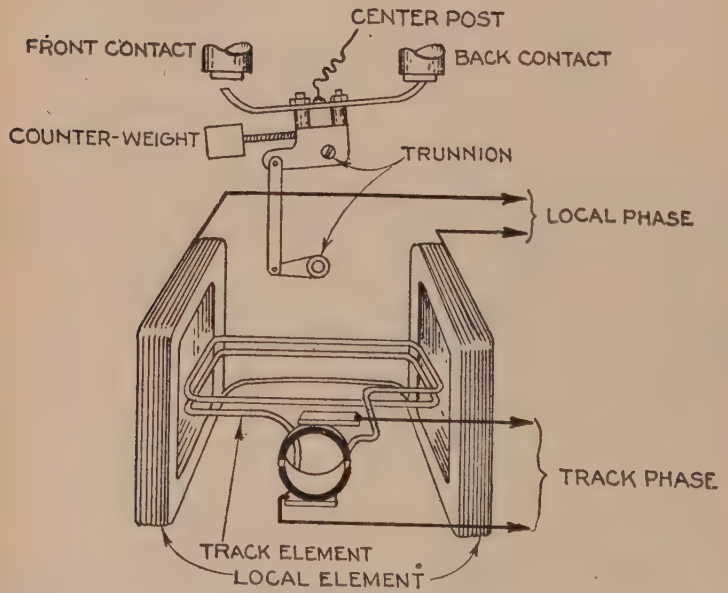


FIG. 6,603.—Ironless galvanometer relay. ***The essential parts*** are the local coils and the armature or track element swinging in the center of the local coils. The armature consists of a comparatively few turns of heavy wire formed and clamped to, but insulated from, a swinging frame attached to the armature shaft. With current supplied to both windings the necessary torque is produced in the armature, rotating the shaft, and operating a contecting link which actuates a pivoted bar carrying the contact fingers. When current ceases to flow in the armature, the torque is no longer existent, and a counter-weight is acted upon by gravity to restore contacts to original position. This relay operates most economically and effectively when its track and local elements are exactly in phase or 180° out of phase.

Another important type is the iron galvanometer relay shown in fig. 6,604.

Single Element Vane Relay.—This is an early type, being the first *a.c.* relay used for signaling purposes. Its construction and operation are shown in figs. 6,605 and 6,606.

Double Element Vane Relay.—This is one of the most efficient *a.c.* relays used in track circuit work. Unlike the single element relay, it is well adapted for operation on long track circuits. It is shown in figs. 6,607 to 6,609.

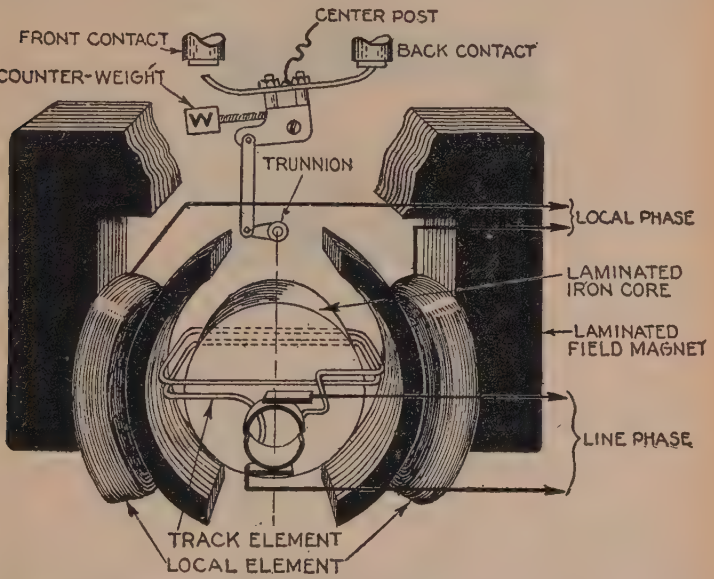
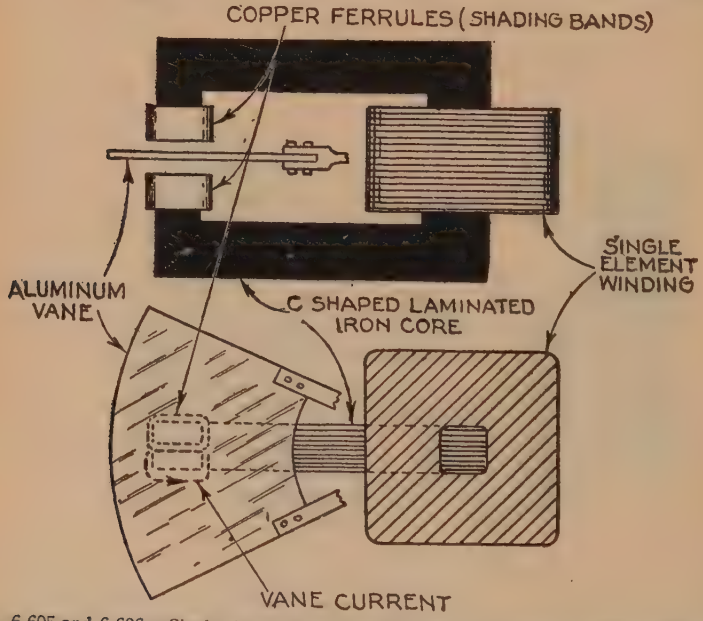


FIG. 6,604.—Iron galvanometer relay. This relay is the same in principle as the ironless galvanometer relay and the constructive design of the two relays would be very much the same, if it were not that an iron magnetic circuit is employed in the iron galvanometer relay. Iron field cores are used to make the relay more economical from the standpoint of power consumption. A strong magnetic field can be produced with a small energization of the local magnetizing coil when an iron core is used. As with the ironless galvanometer relay, this relay operates best when its track and local elements are exactly in phase or 180° out of phase.

Polyphase Relay.—This relay is generally looked upon as being the most economical for track circuit work and it is well adapted for use on long track circuits. This is a double element relay and as shown in fig. 6,610, is operated by a polyphase motor which consists of a non-magnetic

rotating shell or rotor and fixed inner and outer cores, the outer core being the stator on which the windings are placed.

Electric Automatic Train Stop.—On railroads where a close headway between trains must be maintained with a maximum of safety, such as on rapid transit roads, the automatic train



FIGS. 6,605 and 6,606.—Single element vane relay. It has an aluminum vane pivoted and moving vertically between the poles of a C-shaped laminated magnet core. The relay depends upon electro-magnetic induction for its operation. When the coils are sufficiently energized, the vane is caused to move upward between the pole faces of the electro-magnet, the upper halves of which are equipped with shading bands, which in combination with the *a.c.* supplied, give rise to a continuously shifting magnetic flux, producing a continuous torque in the vane. The movement of the vane, by a simple link arrangement, causes the contact shaft on which the contact fingers are mounted to be moved so as to change the contact positions. When the relay is de-energized, the vane which is counter weighted, drops by gravity on to a small fibre roller which acts to bring the vane to rest without shock or rebound. The single element vane relay, from the standpoint of power economy, is not well suited for use on very long track circuits, because the single element winding must receive all its power over the rails, and cannot, consequently, equal the power economy of two element relays on long track circuits, particularly where the ballast is poor.

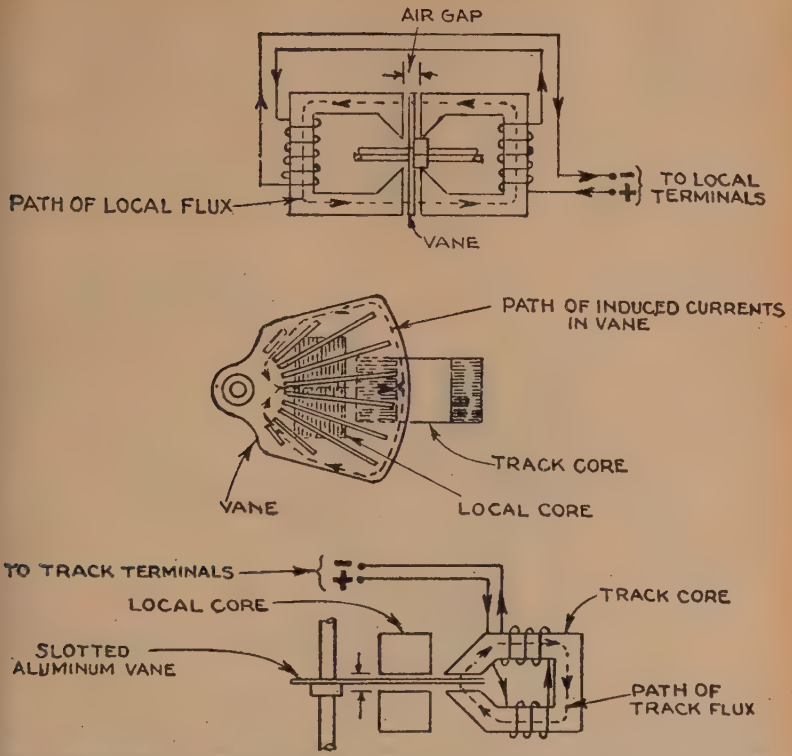


FIG. 6,607 to 6,609.—Double element vane relay. *It has* two local iron cores, one on each side of the vane; one track core which has a pole on each side of the vane at its outer radius. The local and track iron cores are fixed at right angles to each other. A vertical slot is formed by the two U-shaped local cores, and in this the vane is placed so that all the local flux passes twice through the vane but in opposite directions. The result of this flux cutting the aluminum conductors formed by radial slots in the vane is that currents are induced in the vane and are compelled to travel along the paths between the slots. The currents thus induced pass in a horizontal direction between the poles of the track core and lag 90° behind the local flux. When a current is sent through the track winding, it induces a flux across the vane which produces a force on the conductors of the vane at right angles to the direction of the currents. This tends to move the vane in a vertical direction, either upward or downward according to the direction of the currents in the track winding relative to the local current. Unlike the galvanometer relay, the double element vane relay should be supplied with current to its track element as nearly as possible in quadrature, 90° out of phase, with the current in the local element, for most efficient operation.

stop is an essential element which operates in conjunction with the signal to enforce obedience upon the part of motormen to the information conveyed by the signal.

The train stop *assumes that position which would trip and apply the emergency braking system on a train at such times*

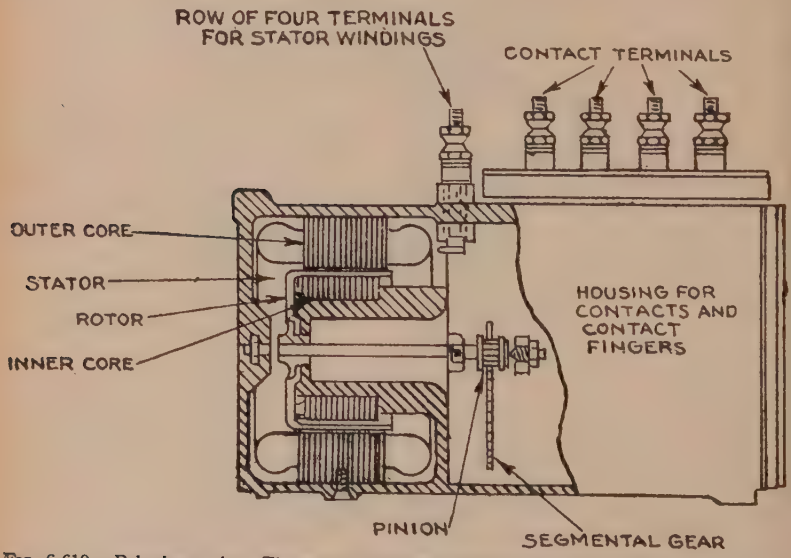


FIG. 6,610.—Polyphase relay. The motor windings are designed and connected so as to produce, with *a.c.* applied, a rotating magnetic field, which in turn induces currents in the non-magnetic rotor causing it to operate. The rotor is ordinarily connected to operate the contact fingers through the medium of a pinion and sector arrangement, thereby multiplying the effect of the rotor and permitting the operation of a large number of contacts with a very small amount of energy applied.

when the signal is indicating stop. One type of electric automatic train stop is shown in fig. 6,611.

Electro-Pneumatic, Automatic Train Stop.—This type of train stop is controlled electrically, but operated by

compressed air. Its essential features and operation are shown in fig. 6,612.

A more recent development of the electro-pneumatic automatic train stop is the rack and pinion type.

In this type the mechanism has been designed along more compact lines. The piston transmits motion to a rack which rotates a pinion on the stop arm shaft, bringing the stop arm to the lowered or clear position. Upon the removal of energy and the consequent release of air pressure from piston,

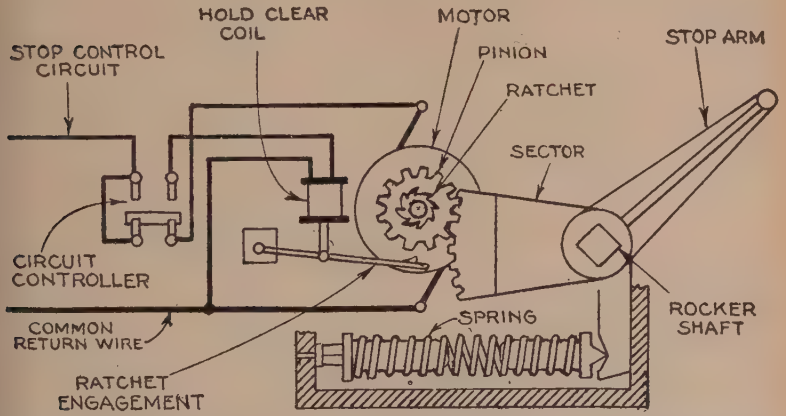


FIG. 6,611.—Electric automatic train stop. It consists of a motor operated pinion and sector mechanism which rotates a shaft to which is attached a stop arm so located with relation to the track and trains as to engage with a tripping device on the train when the train stop is in the stop position. Engagement of the stop arm with the tripping device on the train operates to automatically apply the air braking system on the train. In order to clear the stop and retain it in the clear position, energy must be supplied from the stop control circuit. The motor then operates the geared mechanism which rotates the shaft against the action of a helical spring in such a direction as to lower the stop arm to the clear position. The motor also operates a circuit controller which opens the motor circuit after the stop arm is lowered, and transfers energy to a hold clear coil. The hold clear coil which is in the form of a solenoid operates a device which engages with a ratchet on the motor shaft thus retaining the stop arm in the lowered or clear position, with little current consumption, until such time as electric energy is removed, when spring action restores the motor armature, geared mechanism, circuit controller and stop arm to the original stop position. The stop being held in the clear position only at such times as when electric energy is applied is along the lines of safety since with this arrangement a broken wire would remove energy and cause the stop to assume the stop position. The arrangement is therefore consistent with the basic principle of signaling which requires that the failure of an essential part will cause the signal and its stop to assume their most restrictive positions.

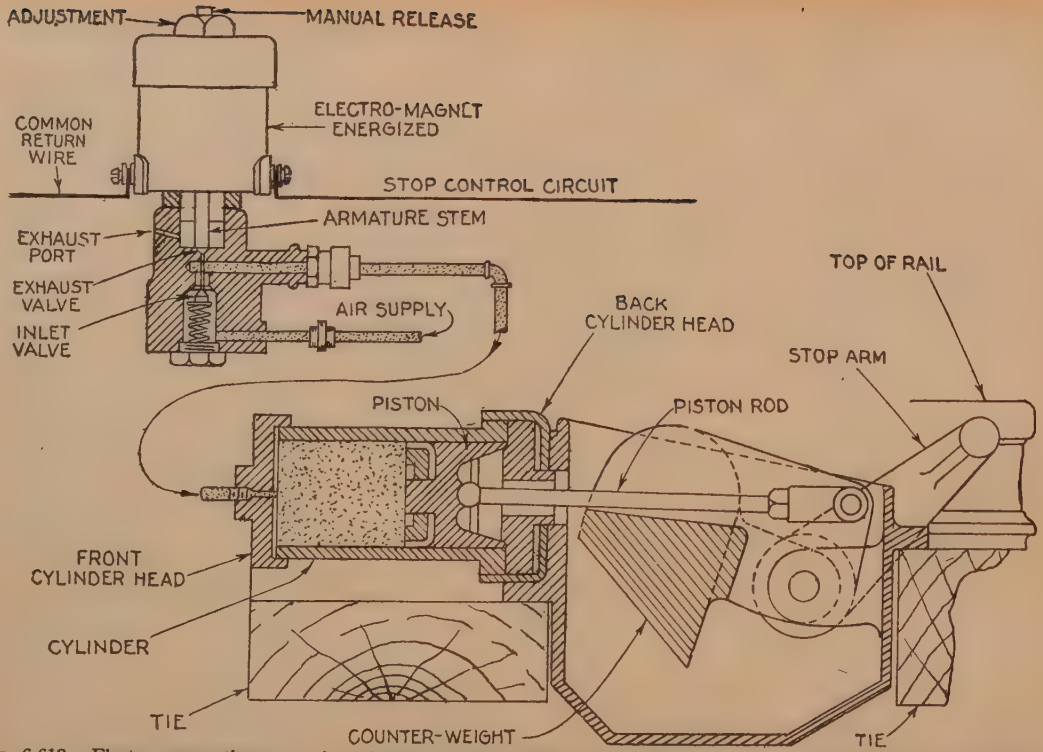


FIG. 6,612.—Electro-pneumatic automatic train stop. ***In operation,*** the energization and de-energization of an *a.c.* electro-magnet operates a pin valve governing the admission to, and release of compressed air from, an air cylinder with piston for the

the rack is moved back by the action of the helical spring under compression, and the pinion on stop arm shaft is rotated in such direction as to bring the stop arm to the engaging position for tripping a train.

Typical Automatic Block Signal Circuit.—The circuit diagram shown in fig. 6,613, is fairly typical of complete electrical controls for an automatic block signal and train stop as used in the New York subways where the overlap system of signal control is a necessary feature and where color light signals are used. This circuit has been chosen as presenting most in the way of signal control principles.

An understanding of the principles involved will therefore cover the necessary part of their application to less complicated conditions such as would be encountered on steam railroads. It should be remembered that signal control circuit design is subject to many ramifications, depending upon the conditions to be met and the degree of safety to be provided.

Signal Overlap Control.—This form of signal control is essential *to maintain the proper spacing of trains running on a close interval.*

It provides for overlapping the line control of a signal into the block section beyond the immediate or home block into which the signal governs train movement.

FIG. 6,612.—*Text continued.*

mechanical movement of the stop arm. With magnet energized, armature and armature stem are drawn down, closing exhaust valve and opening inlet valve. Path of compressed air is then from air supply line, through inlet valve, through piping to air cylinder on stop mechanism. Piston in stop cylinder is moved to the right against back cylinder head. Movement of piston is transmitted along piston rod rotating counter-weight upward against gravity, and stop arm to clear position. When magnet is de-energized armature and armature stem are sprung up, closing inlet valve, thereby shutting off air supply. Exhaust port in magnet valve is open permitting air to exhaust from air cylinder at stop mechanism, through piping, through exhaust valve, through exhaust port to atmosphere. Counter-weight is acted upon by gravity and rotated to low position, bringing stop arm to upright or engaging position. It will be noted from the foregoing that a broken stop control wire or a break at any point in the air line would permit counter-weight to be acted upon by gravity to place stop arm in the engaging position to trip a train, also setting the signal at stop indication since the red light at signal receives energy direct through closed contact on stop circuit controller when the stop arm is in the tripping position. The circuit controller operates to change its contact positions with the positions of the stop arm.

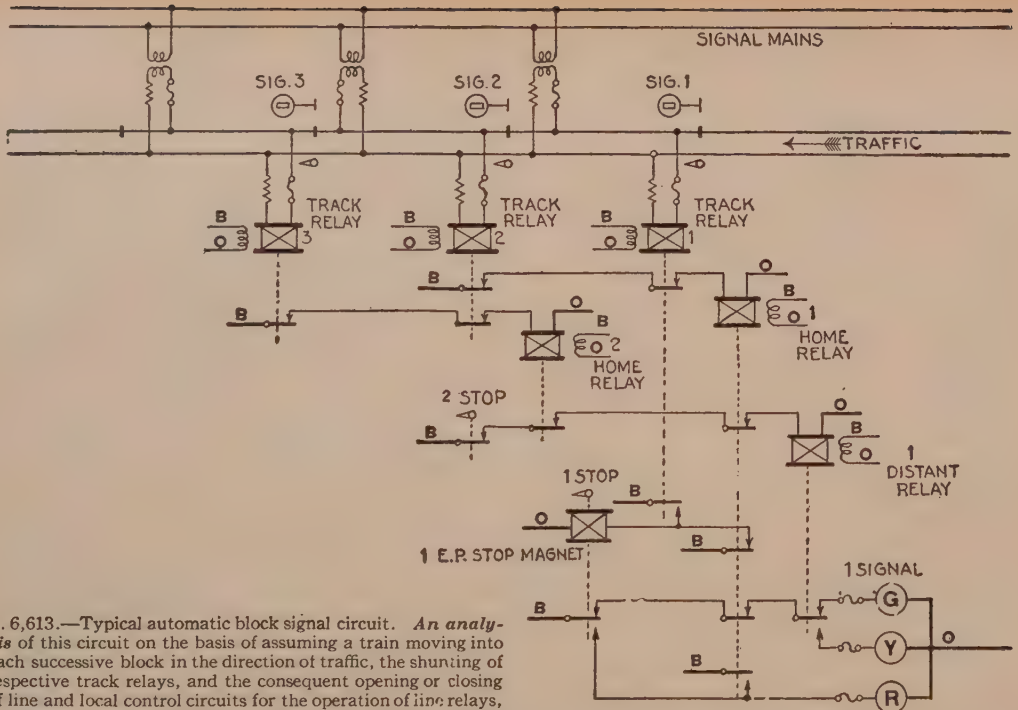


FIG. 6,613.—Typical automatic block signal circuit. ***An analysis*** of this circuit on the basis of assuming a train moving into each successive block in the direction of traffic, the shunting of respective track relays, and the consequent opening or closing of line and local control circuits for the operation of line relays, stop mechanisms, signal lights, etc., should make it clear to the reader that the signal indications in the rear of a train are such as to provide complete overlap protection, and that the coordination of stop arm position with signal indication is such as to trip a train should the information which signal conveys be disregarded. The reader is referred to "Signal Indications" covered in Chapter 145 on Railway Signals.

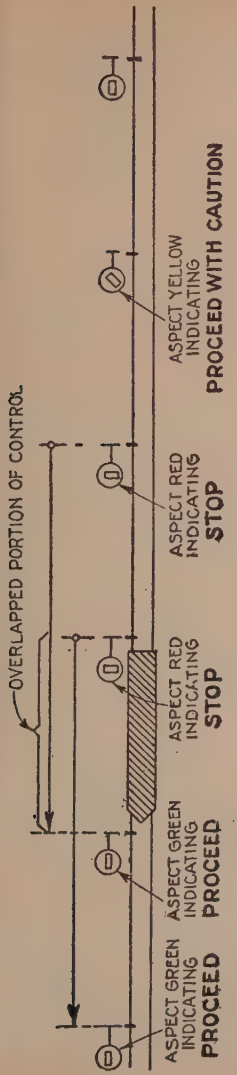


Fig. 6,614.—Signal overlap control.

As will be seen from fig. 6,614, there are always two signals displaying the stop indication in the rear of a train. Since the signals are located so as to provide braking distance for maximum speed of trains, plus a factor of safety, between each two signals, the system provides for a safe spacing of trains.

Scientific Location of Signals.—Signaling of a railroad is based on space intervals determined by time and not by distance.

Knowing the maximum number of trains per hour or the shortest time interval between trains, it is possible to signal a length of track which will keep trains moving without any check or stop, other than those required at stations.

On suburban lines, or where the traffic is light, the spacing between signals may be of considerable length and is subject to some latitude; but on congested lines and on rapid transit railways, the spacing of the signals is close and their location has become an exact science.

The location of automatic block as well as interlocking signals on railroads of this character can only be determined with careful consideration being given to the following elements:

1. Headway of trains and length of time of station stops.

2. Physical characteristics of the line. This includes such factors as grade and alignment of tracks, locations of switches, stations, etc.

3. Average and greatest length of train.

4. Permissible and possible speeds of trains over the sections to be signaled.

5. Operating characteristics of signal apparatus.

6. Motor and braking characteristics of car equipment.

This includes acceleration rates as well as deceleration rates for both emergency and service braking of loaded trains on level track and various grades.

7. The system of train operation, and required train movements at interlockings.

These elements enter into the basic design of the signal system and most of them can be set down at fairly definite values, and the usual practice is to combine the known quantities in proper relationship, in the form of operating curves, these curves being plotted for the entire length of each track.

By placing side by side the curves of two consecutive trains operating on the required schedule, the locations of signals between the two curves may be scientifically determined so as to meet the operating requirements.

In locating the signals, however, allowance must be made for the indefinite elements in the problem, and for the deficiencies in the car and roadway equipment. These curves represent the probable operating speed of the trains, on the required headway, which takes care of the capacity element of the problem, but the signal locations must also take care of the safety element, and the length of control of each signal spotted between the two operating curves must be such as to provide braking distance at maximum speed. A system of signaling laid out in this way will make for an equable movement of trains with a maximum of safety.

Speed Control of Signals.—This system of signal control *finds its greatest usefulness on rapid transit railroads.*

Perhaps the most important use of the speed control signal is *for closing in trains at busy stations where the duration of station stop is greater than at other stations of the line.*

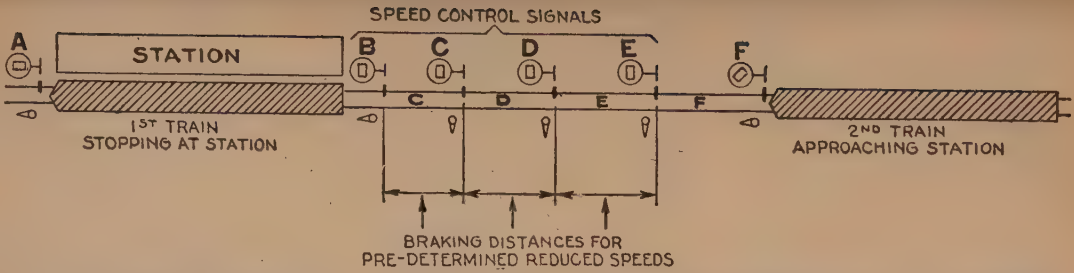


FIG. 6,615.—Speed control of signals. ***In operation*** a second train upon entering a signal block F, sets in motion a time element relay. Through the contacts of this relay the control circuits for signal E, are carried in such manner as to hold this signal and its automatic train stop at danger. The time element relay operates to pick up on a time interval. That is, upon receiving energy with the passage of second train into signal block F, the relay will operate to change the position of its contacts after a certain fixed interval of time has elapsed. This time interval is pre-determined depending on the speed at which it is necessary to hold trains, and relay is set accordingly. With a train moving through this block at prescribed speed, time element relay will operate to clear signal E. This process is repeated on train's approach to signal D, and so on. If train should exceed speed limit in any block, it will have arrived at speed control signal before the time element relay has operated to clear signal, hence train will be tripped. With no trains stopping at station, circuits are so arranged that speed control signals do not function as such, but give clear indications, allowing train to pull into station without reduction in speed.

This long station stop is a limiting factor to headway and while everything is done to reduce its duration there is a fixed minimum under which there can be no further reduction. The speed signal in this case operates to allow a train to approach close to the station at reduced speed when the station track is already occupied by a train. This reduction of approaching train's speed lessens the braking distance required between the train in station and approaching train, hence there is no sacrifice of safety. The consequent reduction of the distance between train about to depart from station and train about to enter station saves time in the operation proportionately as this distance is reduced. This reduction of time between trains passing through a station increases the number of trains that can be operated through the station per unit time, hence shortens headway or increases carrying capacity. How this closing in of trains to station at reduced speed is accomplished is shown in fig. 6,615.

Not only does the speed control signal save time when closing in trains at stations, but its tendency is *to keep trains moving*.

This is a decided advantage, from the standpoint of power consumed in starting trains.

The speed control signal may also be used to advantage to compel a pre-determined reduced speed on curved sections of track and on long steep down grades where safety may require a check on train speed, and over slow speed switch layouts.

In such cases, where the regulation of train speed is required, at all times, the circuits are arranged so that the speed control signals are normally at danger and clear always on a time interval with the approach of a train.

In other respects the process of governing the speed of the train is similar to that already described.

Speed control signals are most effective when the signal blocks through which the speed of trains are controlled are comparatively short, say 200 feet, approximately. This arrangement removes the possibility of a motorman moving his train at very slow speed in the forward part of the block and accelerating beyond unsafe limits in the remaining portion.

TEST QUESTIONS

1. *What is the primary purpose of automatic block signals?*
2. *What is a block?*
3. *Define home and distant signals.*
4. *How does single track signaling differ from double track signaling?*
5. *Describe at length the method of single track signaling.*
6. *What is the object of the absolute permissive block system?*
7. *What is the principle of* d.c. *track circuits?*
8. *How does the normally closed track circuit differ from the normally open track circuit?*
9. *Describe a* d.c. *battery fed track circuit.*
10. *Explain at length the basic principle of signaling.*
11. *Draw a diagram showing effect of a train in the block.*
12. *What determines the choice between end fed and center fed circuits?*
13. *Draw a diagram of a normally open type battery fed track circuit.*
14. *What are the advantages of an* a.c. *track circuit?*
15. *Describe a single rail track circuit.*
16. *Where should a double rail* a.c. *track circuit be used?*
17. *What is an impedance bond?*
18. *Draw a diagram of a single rail track circuit.*
19. *Describe the various types of relays.*

20. *What is an electric automatic train stop?*
21. *Describe the electro-pneumatic automatic train stop.*
22. *Draw a diagram illustrating single overlap control.*
23. *For what service is speed control of signals used?*

CHAPTER 147

Interlocking

By definition interlocking is *the operation of a system of switch, lock and signal apparatus so inter-connected that the movements of all members of the system must succeed each other in a predetermined order.*

Interlocking governs the movement of trains over conflicting routes, as distinguished from block signaling which governs the movements of following or opposing trains over the same route.

Interlocked switch and signal appliances were first devised and used at junctions and terminal points for the purpose of reducing the number of men employed to go from switch to switch, throw them by hand and then give a hand signal for the train to proceed over the route thus lined up. It was soon found that operating the switches and signals from a central point under the control of the levers in an interlocking machine greatly expedited the handling of traffic. By far the greatest accomplishment of interlocking, however, was the addition to train operation of an enormous factor of safety at such points.

Four distinct systems of interlocking have long been known and are in wide use:

1. Mechanical;
2. Electro-mechanical;
3. Electric;
4. Electro-pneumatic.

The last three are classed as power systems as distinguished from the mode of operation of the first which is by hand.

Each of these four systems is more suitable than any of the others for use in some places and under some conditions. It is often the case, that the decision which system to use, is obvious; but it is also often the case that the decision is close and calls for much study and for sound judgment, the latter presupposing accurate knowledge of many facts.

Power interlocking, like power signaling, had its origin and its engineering and commercial development in the United States.

This relates to the art as actually applied on a large scale to practical use. There were European inventors early in the field, but their inventions were not of real importance until long after the electro-pneumatic interlocking had become in the United States a well known and highly developed means of safety and economy. Interlocking is an example of the use of machinery in place of men.

An interlocking plant consists of *a group of levers concentrated at a central point for operating certain switches and signals, and so arranged as to interlock such levers and make it impossible to give clear signals for conflicting routes*. The advantages derived therefrom are safety, facility of operation and saving in cost of manual labor employed.

Distinction is made between several kinds of locking, classed as:

1. Section locking;
2. Sectional route locking;
3. Approach locking;
4. Stick locking;
5. Check locking.

Section Locking.—Section or detector locking consists of *the control of switches by track sections which may form a part or all of a route and of which the switches protected are a part.*

Sectional Route Locking.—It is desirable to prevent the manipulation of any switch after a train has passed a signal governing movement over that switch, no matter how remotely the signal may be located from the switch in question. This leads to the control of a switch by more than one track section, or route locking.

Where traffic is heavy it is also desirable that the switches be released as quickly as practicable after a train has passed over them. That is, the switches in one section may be released while those in another section of the same route are still electrically locked, for traffic in a certain direction. This is a question of expeditious handling of traffic and not of safety and is called sectional route locking.

Approach Locking.—In the early days of interlocking, some assurance of protection against a switch being changed in position, after a train had accepted and passed a clear signal, was provided by the introduction of a time element between the return of the signal to stop and the movement of the switch points. This was called time locking. It is evident that under certain operating conditions complete reliance for safety cannot be placed upon a time interval, so that in most power interlockings to-day what is called approach locking has superseded time locking for high and medium speed routes.

Approach locking provides that *while a train is approaching an interlocking signal which indicates proceed, the switches over which this signal governs train movement cannot be changed in position.*

The leverman always has the ability to cause signals to assume their most restrictive positions, as it may become necessary for him to stop a train after he has once cleared the signal for it to proceed. Approach locking provides that he cannot, even after restoring the home signal to a stop position, immediately change position of any switch which might affect the route for train movement. A provision to take care of an emergency requirement is made by the use of a clockwork time release not mechanically connected to the lever.

Ordinarily approach locking circuits are made effective as soon as a train enters the track circuit approaching the distant signal, so that if the distant signal indicates proceed the train is protected long before reaching the home signal near the derails and switches.

Stick Locking.—This is another form of approach locking, being different in that it becomes effective upon the reversal of the home signal lever and does not further depend on the approach of a train.

Check Locking.—This consists of *the intercontrol between levers in separate interlocking machines*. This is ordinarily required when provision must be made for reversing the normal direction of traffic between two interlocking plants.

It is accomplished electrically by means of lever locks which are similar to those used in connection with approach, route and section locking. There must be cooperation between levermen before a signal can be cleared for train movement onto the track protected.

The methods of accomplishing the various kinds of locking are explained in later chapters.

TEST QUESTIONS

1. *Define the term "interlocking."*
2. *Name four distinct systems of interlocking.*
3. *Of what does an interlocking plant consist?*
4. *Explain briefly:* 1, *section locking;* 2, *sectional route locking;* 3, *approach locking;* 4, *stick locking;* 5, *check locking.*

CHAPTER 148

Electric Interlocking

Briefly, electric interlocking is that method of interlocking in which the operated units *are operated and controlled by electricity*.

The elements comprising an electric interlocking system are:

1. A source of power serving as a central energy supply for the entire interlocking.

2. A means of distributing energy to the various units for control, operation and indication.

3. The interlocking machine which places all units within the limits of the plant under the control of a leverman.

4. Motor operated switch and lock mechanisms for unlocking, throwing, locking and indicating the positions of various switches.

5. Mechanisms for clearing signal blades in response to lever movements.

6. Auxiliary devices such as tower indicators, track model, time releases, etc.

7. Automatic electric control exercised through the agency of track circuits, approach, route and detector locking.

Power Supply.—Either *d.c.* or *a.c.* may be used to operate an electric interlocking system. The *d.c.* type will first be described in detail. An essential requirement as to power is that there be no interruption of traffic so that either the source of power must be infallible or arrangement be made for emergency supply.

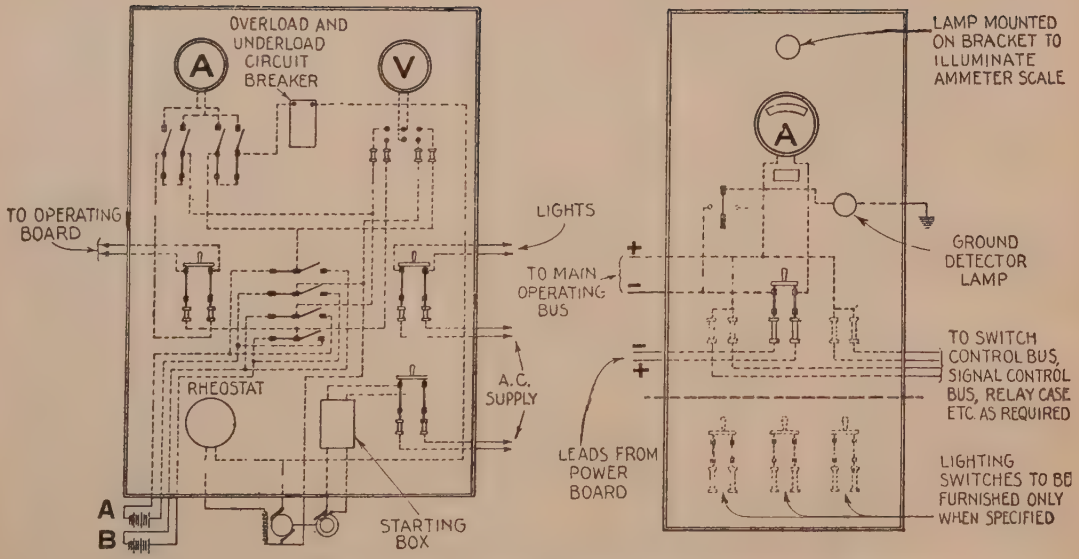


FIG. 6,616.—Power switchboard. Ordinarily located adjacent to dynamo or converting equipment and battery.

FIG. 6,617.—Operating switchboard. Located in the operating room where it can be observed by the leverman. The power and operating boards are ordinarily of one small panel each.

Energy may be obtained from a commercial source or may be generated at the interlocking plant. The former constitutes the usual practice. When commercial power is not available, either steam or gas engine driven *d.c.* dynamos may be used. For an average plant, the dynamo will be from 2 to 3.5*k.w.* the exact capacity depending upon the storage battery used. Power obtained from a commercial source is nearly always in the form of alternating current.

On *a.c.* electric roads, a line transformer will reduce the transmission voltage to either 110 or 220 at the interlocking tower. *A.c.* at this voltage can be readily converted to *d.c.* by means of either a motor generator or a rectifier.

An average plant will require either 55 cells of lead type battery or 90 cells of nickel iron alkaline battery, the capacities varying from 120 to 200 ampere hours in either case. The generating equipment and battery are ordinarily housed in the lower story of the tower.

Power Distribution.—The greater part of the energy is distributed by means of bus mains which extend throughout the plant. These are of heavy wire of low resistance, providing practically normal voltage for the operation of each unit, no matter how remotely located.

The bus mains supply current for the operation of both switches and signals of the electric interlocking, and if desired, for signal lighting.

Switch and Signal Operation.—This constitutes by far the heaviest momentary load on the interlocking battery. A 110 volt *d.c.* switch motor requires from 3 to 4 amperes for 2 to 3 seconds per switch movement.

A signal motor takes less than 1 ampere for 5 seconds to clear the signal.

It is essential *that there be no very great drop in voltage from the tower to the unit during its operation;* the bus main multiple supply system insures this.

An interlocking plant generally includes switches and signals distributed in such a way as to provide maximum facility in handling traffic, and with

obviously no regard to their concentration in such a manner as to secure the same drop in voltage during the operation of one unit as another.

Signal Lighting.—Power for signal lighting is ordinarily supplied by separate lines leading from the operating switch board, but if desired, signals can be lighted from the bus mains.

Electric Locking.—Modern interlocking incorporates *all the*

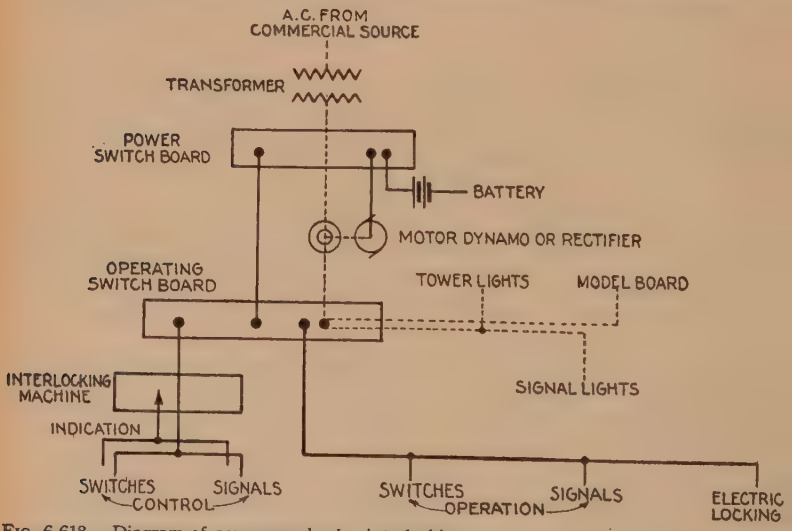


FIG. 6,618.—Diagram of power supply *d.c.* interlocking.

safeguards in the form of electric locking that are necessary to insure the safe passage of trains at such speed as the physical condition of the track will allow. Approach, route or sectional route, and section locking provide this. Most of the electric locking relays receive their energy from the bus mains.

Relays of 1,000 ohm resistance are connected in series with 9,000 ohm resistors to the 110 volt wires. Although the power requirement per unit is not of material consequence, the total energy taken is a considerable portion of that required for the entire interlocking.

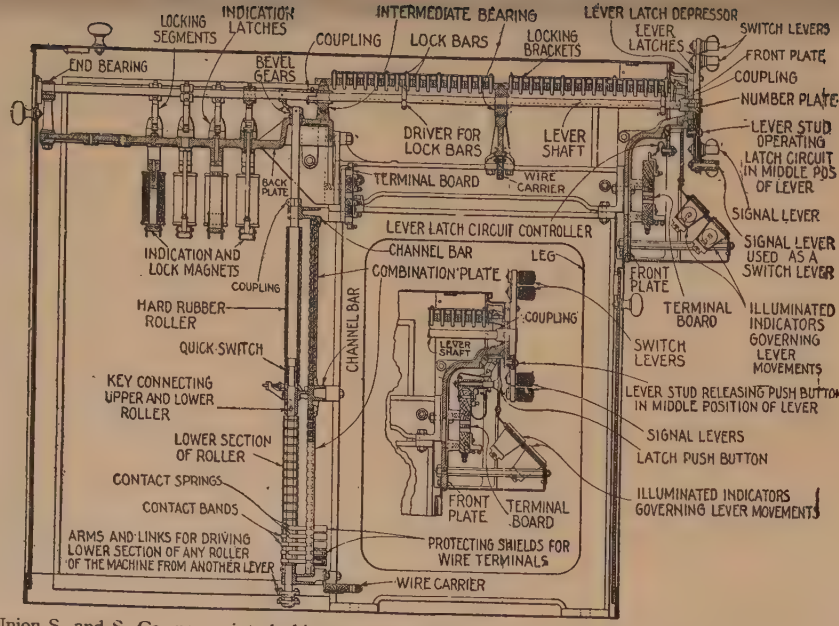


FIG. 6,619.—Union S. and S. Co. power interlocking machine, end view.

Track Circuits.—*A.c.* track circuits are often installed at *d.c.* interlocking plants.

The Interlocking Machine.—The principle of interlocking requires that *before a signal can be cleared for the movement of a train, all switches, derails and frog points, over*

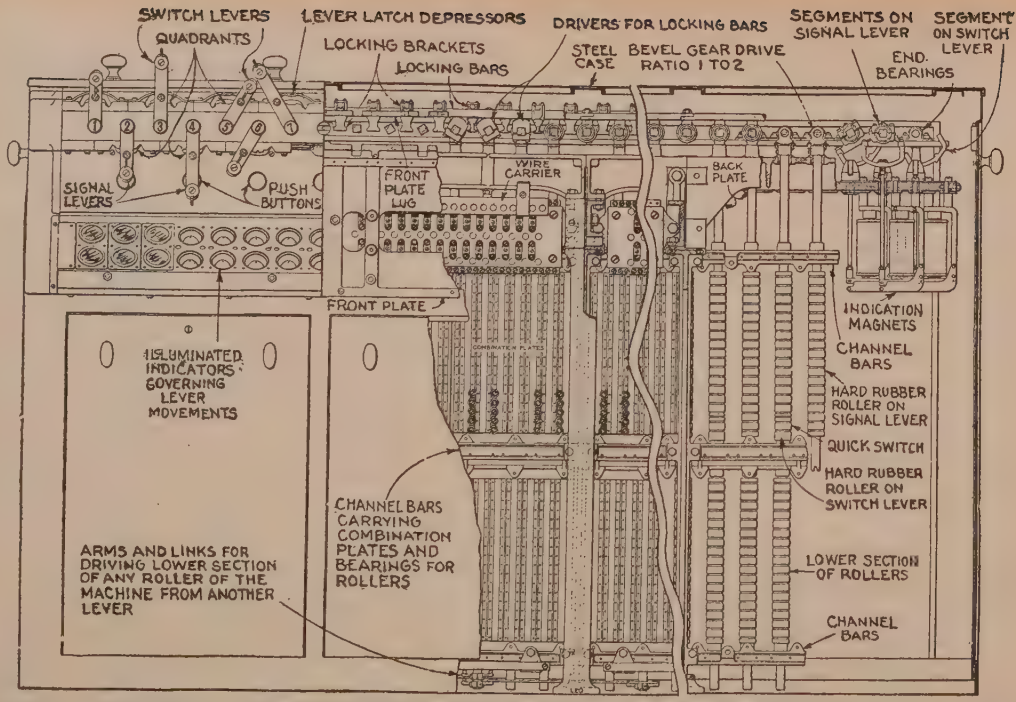


FIG. 6,620.—Union S. and S. Co. power interlocking machine; front view. This machine provides for the control of as many switches or as many signals by a single lever as is practical without limiting possible simultaneous traffic movements. ***Example:*** both ends of a cross over are controlled by a single lever, also opposing signals, only one of which can be cleared at a time, may be controlled by the same lever. Safety as well as simplicity is secured by a single lever controlling conflicting signals, as the interlocking of these is obtained directly through lever movement and not by means of the dogs and locking

which the signal governs train movement, shall be in proper position and locked. To secure such protection for train movement it is desirable to concentrate the control of the various switches and signals at one point. The mechanism in which this concentration of control is secured is called an interlocking machine, as shown in figs. 6,619 and 6,620.

The machine consists of small hand thrown levers, compactly located in a frame and arranged for the operation of circuit controllers, but restricted in their movement by both mechanical locking and electric locks.

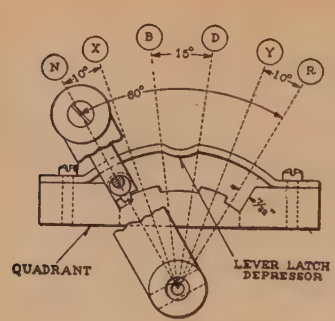
Lever Manipulation.—The multiple control of either switches or signals from single levers naturally results in a considerable reduction in the size of the machine and consequently the tower space required.

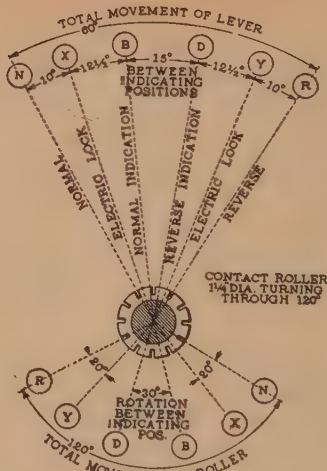
As indicated in figs. 6,621 to 6,624, each lever rotates through a 60° angle in a plane parallel with the machine. Thus a leverman may operate two widely separated levers at one time, pulling them toward his body or thrusting them away as required. The complete operation of a track switch from either of its two positions is effected by a partial movement of its lever, the complete movement being impossible until the switch responds to the partial movement.

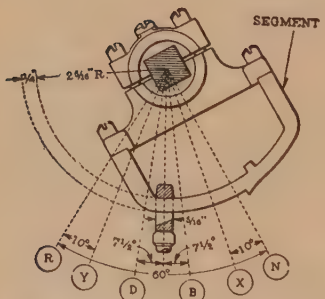
Two circuits are employed before the lever movement can be completed, one for effecting the switch operation, and one for releasing the lever for its final movement, the latter being the switch indication circuit.

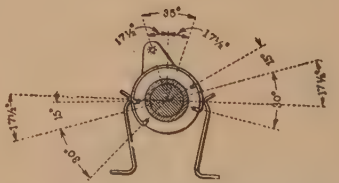
The complete operation of a signal from stop to proceed is secured by a continuous, complete lever movement, but its release from proceed to stop necessitates a preliminary lever movement for interrupting the power supply, and a final movement that can be made only after the signal has returned fully to the stop position.

The operation of switches and signals thus involves the opening and closing of contacts in electric circuits during and at definite points of lever movement. The restraint of lever movement by the switches or signals is accomplished by means of electric locks according to the energized or de-energized state of their magnets. The control of these electric locks is not restricted solely to switch and signal operation, train location being at times a factor in it. The accompanying illustrations show details of the switch lever.









FIGS. 6,621 to 6,624.—Diagrams of switch lever. Fig. 6,621, represents the several position of a switch lever during the operation of a switch, and shows the formation of the quadran secured to the front of the machine frame and that of the lever latch carried by the lever These are involved in restricting lever movements. This figure also illustrates means fo forcing the lever latch into engagement with the quadrant at mid-stroke, so that this quad rant and not the segments of the electric locks will receive the impact of the lever's arreste movement, thus insuring entire freedom of action for the latches of the electric locks wher these are lifted by the magnet to release the segment for final lever movement after the indication has been received. Incorporated in this figure is the stud or pin which co-acts with the latch to open and to maintain open a set of contacts for certain positions of the latch and lever in order to avoid useless consumption of energy from the battery. Fig 6,623, shows one of the two segments and latches of a switch lever that are employed jointly for switch indication and section circuit locking. Fig. 6,622, shows diagrammatically the several positions occupied by a switch lever, as previously mentioned, and the angle o rotation that the lever movement imparts to the contact roller of the machine. The rollers move through double the angle through which the levers turn. Fig. 6,624 shows a section of the roller that is not continuously movable with the shaft, being restrained from fol lowing it during preliminary lever movement by a spring actuated toggle and until the

Checks on Lever Movement.—Considering first mechanical locking, in order that a signal may not be cleared until every switch, derail, and movable point frog over which it governs is in the proper position and locked, it is necessary that the movement of the levers in the interlocking machine be made in proper sequence. This is the function of the mechanical locking, and it is accomplished by: First, the release of one lever for operation only after another has been fully operated; and, second, by the locking of one lever against operation by movement of another before this movement has advanced sufficiently to cause any change in the position of the switch or signal which it controls.

It will be seen from fig. 6,625 that the movement of each switch lever is governed by two magnets together with their latches and segments. These serve not only as indication locks for restraining final movement of the lever until the switch has responded, but also as detector or track circuit locks, preventing the preliminary movement of the lever in case the track is occupied.

Prior to the movement of the lever to change the position of the switch from normal to reverse, the normal indication magnet must be energized, and this is possible only when the track section in which the switch is located is unoccupied. Correspondingly, before the lever can be moved from its reverse position, the reverse indication magnet must be energized, this also being possible only when the track section is unoccupied.

Assuming that the lever has been moved from its normal position to the reverse indication position D, fig. 6,623, the reverse indication magnet must become energized before the lever stroke can be completed. This energization is possible only when the switch has assumed its reverse position and allowed current to flow to the corresponding indication relay. Before the lever can be returned to its normal position the normal indication magnet must be energized, this showing that the switch has again completed an operation in co-ordination with the lever movement.

While one magnet thus permits the start of the lever to effect switch operation, the other insures that before the lever stroke can be completed the switch shall have responded to the lever movement and has been locked in its corresponding position.

IGS. 6,621 to 6,624.—*Continued.*

final movement of the lever occurs after the indication has been received. This device functions as a part of the indicating system and is known as the *quick switch.*

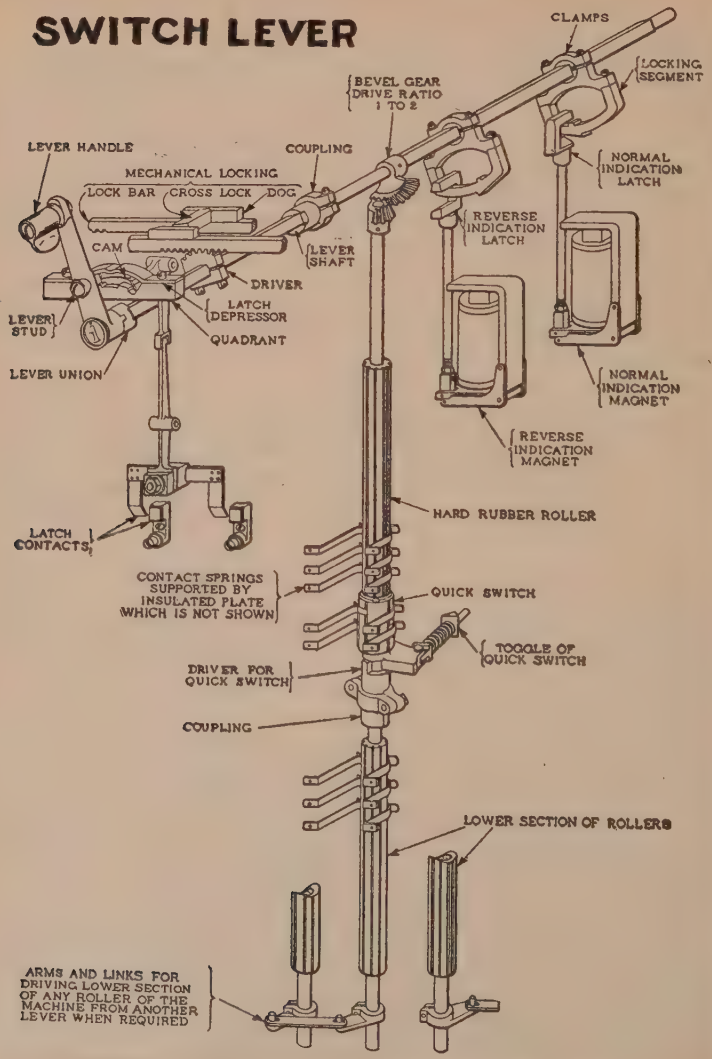
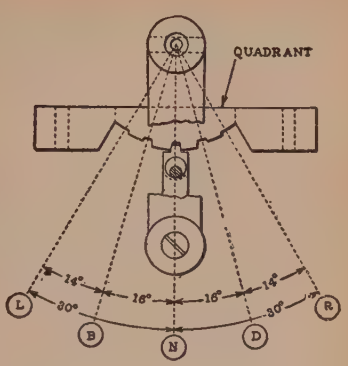
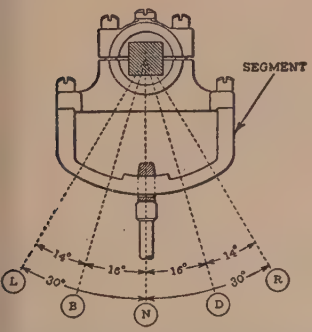


FIG. 6,625.—Perspective diagram of switch lever unit and its relative parts.





The final movement of the lever transfers the magnet which permitted such movement to the duty of locking the lever in its new position automatically when the track is occupied. Simultaneously with this action the other magnet is withdrawn from its section locking service and transferred to the indicating function required for the next operation of the switch.

FIGS. 6,626 to 6,628.—Diagrams of signal lever. The signal levers occupy five distinct positions as shown in the diagrams, when used to their full capacity. By full capacity is meant the use of a lever movement to the right for the operation of one signal or set of signals and to the left for another signal or set of signals, the two sets necessarily conflicting with each other in respect to the route or routes governed. The signal levers normally occupy a central or vertical position. When thrown to the extreme right the signal cleared allows traffic movement over a given track in one direction, and when thrown to the left another signal will clear, allowing traffic over the same track, but in an opposite direction. The signal lever cannot be returned to its central position from either extreme until all signals affected by its movement in either direction are in their most restrictive positions. A partial movement of the signal lever from either of its extreme positions causes a break in the signal holding circuit previously supplied with current, thus allowing the signal blade to assume a restrictive position. Positions B, and D, represent those assumed by the signal lever when moved from either extreme position, represented by lines L, and R, to restore the signal to its stop position, and beyond which the lever cannot be moved toward its central, normal position until the signal has assumed its restrictive aspect.

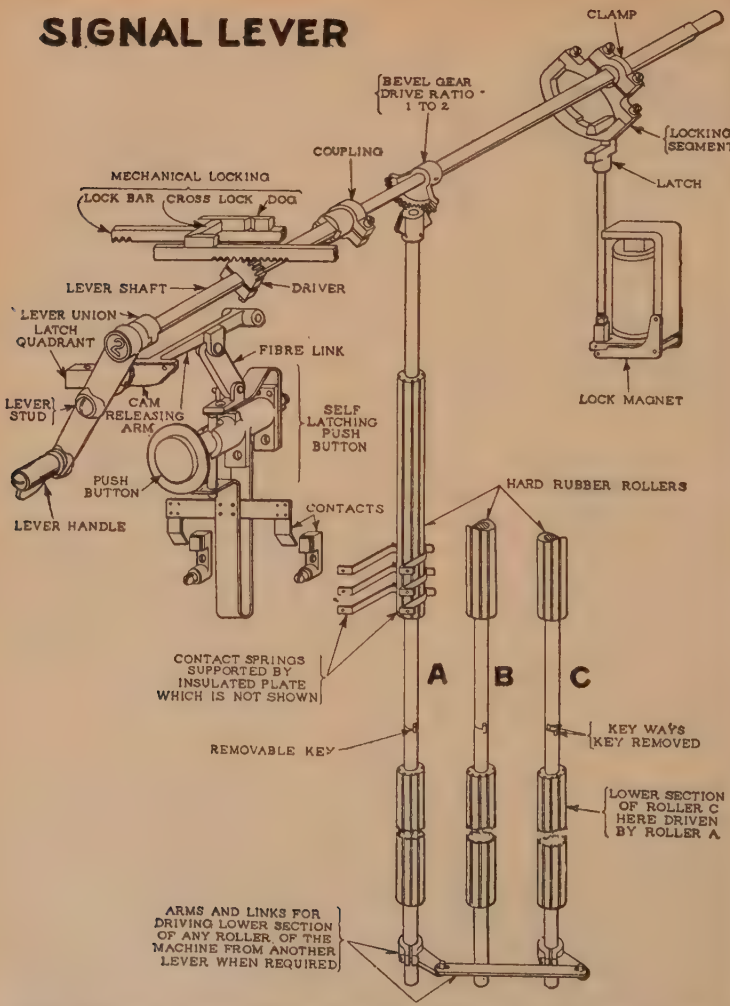


FIG. 6,629.—Perspective diagram of signal lever showing relation of the various parts of a complete signal lever unit. The push button shown immediately under the lever handle provides for the operation of calling on signals.

This transfer of the magnets from one field of usefulness to another occurs only at the completion of each full lever operation, and is performed jointly by what is termed the quick switch, and by what are designated as X and Y, springs of the contacting system.

The signal section symbols for the springs last mentioned are NX, and RY.

Only one electric lock magnet is required for the signal lever, as it is necessary in case of signals to indicate only the return of the signal blade to its most restrictive position, at which time the lock will become energized and the latch lifted, so that the lever stroke may be continued from either extreme position to the normal position which is central. This will be noted by reference to figs. 6,626 to 6 628.

Contact System.—The contact rollers are mounted with their axes vertical. The contact springs are mounted upon a panel or plate of moulded insulation which also supports the terminal binding posts to which outside connections are made.

Lever Lights.—The front plate of the interlocking machine is constructed with a recess under the levers so that lever lights or push buttons may be installed where required.

The former may be made to repeat the positions of either switches or signals or to show the track occupancy which may affect the movement of any switch.

On many roads the stop position of a signal is repeated by a red lever light indication, released when the lever is put normal. The push buttons are used for calling on arms and may be applied in connection with either electrical or mechanical stick control.

Switch Movements.—The operation of switches, derails, and movable point frogs is one of the most important functions as well as constituting the greatest load, of an interlocking plant.

Safety demands that the switch shall be finally locked in position when a train is passing; economy in handling traffic demands that there shall be no unnecessary loss of time in effecting the change of a switch from one position to the other.

The mechanism which meets these conditions must do its work in the following sequence:

1. Unlock;
2. Throw;
3. Lock switch points;
4. Indicate.

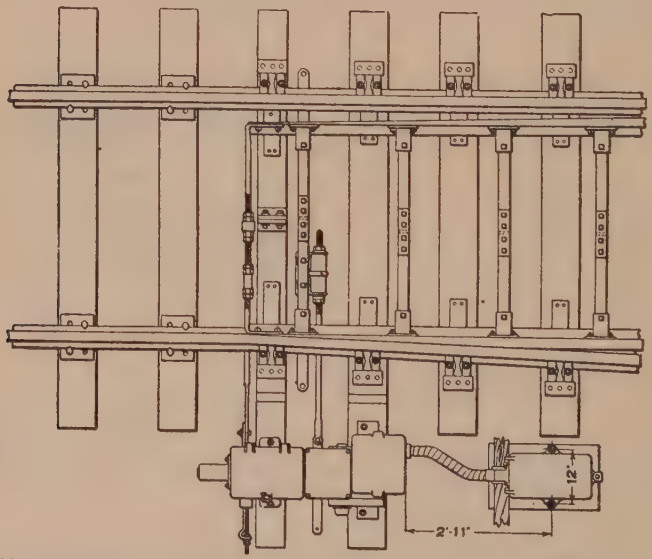


FIG. 6,630.—Single switch layout.

Fig. 6,630 shows an application of the single switch movement wherein it will be noted that the mechanism case is provided with four lugs for fastening it to two ties. The frog movement as shown in fig. 6,631 is slightly longer because of the extension necessary to take in the additional lock rod, and is arranged with six lugs for mounting on three ties.

Switch Control.—Fig. 6,632 shows the switch control circuit

between the interlocking machine bus and the controller which is located adjacent to the switch movement.

Controller.—This is housed in a cast iron box mounted on a concrete foundation adjacent to the switch and lock movement, but independent of the track. Therefore, it is not integral with the switch and lock mechanism which, of necessity, is directly connected to the rails and ties.

The controller for *d.c.* interlocking is normally de-energized; that is, it requires current only when changing from one position to the other, and this

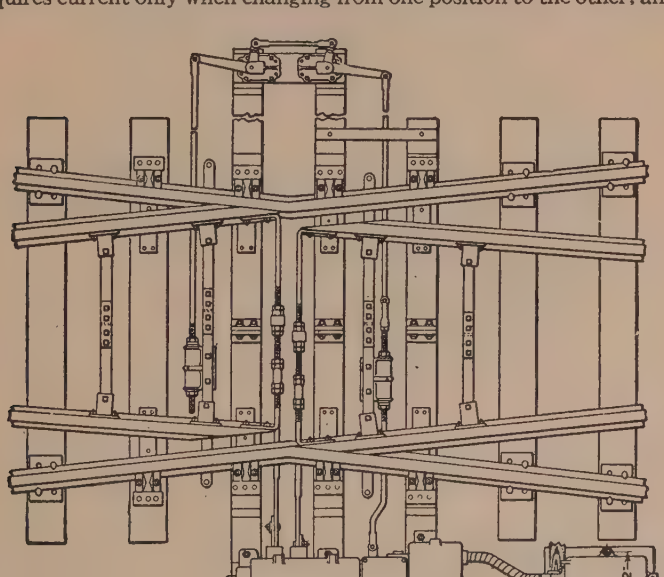


FIG. 6,631.—Frog layout. One pair of the frog points is operated directly from the movement, motion being transmitted to the other set of points through a combination of two crank arms. A pair of short arm cranks are recommended, rather than a single straight arm crank.

is accomplished in less than a second. The controller is illustrated in figs. 6,632 to 6,635.

The operation of the controller will be more clearly understood by following through a description of what happens when the interlocking switch lever is thrown from normal to reverse, and, after the switch movement has operated and indicated, returned to its normal position. See figs. 6,634 and 6,635.

When lever L, is reversed, positive battery from the machine bus will be connected to wire 1RW, and current will flow through wire 1RW, contact X, wire W5, to neutral magnet N. Magnet N, is permanently connected to negative bus wire CH.

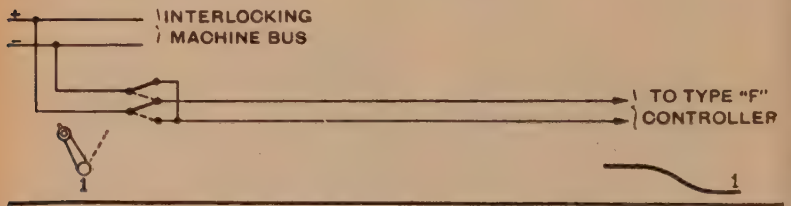


FIG. 6,632.—Switch control circuit. The contacts of lever 1, through which this circuit is broken, function as a pole changer as indicated in the diagram. It will be noted that the switch control circuit consists of two wires only, these running without interruption from the interlocking machine contacts to the terminal board on the controller at the switch. These wires are used for no purpose other than for the control of the switch movement.

The energization of magnet N, causes its armature to be attracted, closing contact between wires 1RW, and W6; W7, and BH; and opening the connection between wires 1W8, and BH. Current will then flow from wire 1RW, through front contact operated by magnet N, wire W6, polarized magnet coils P1, and P2, wire 1NW, lever contact L, to negative machine bus. It will thus be seen that the operating circuit for the type F, controller does not include a common return but is a separate metallic circuit going out over lever contacts to one wire and returning over the lever contacts via another wire.

A local circuit through the other front contact operated by magnet N, is also closed for the purpose of energizing magnet P3, the function of which is similar to that of the permanent magnet used in a polarized relay.

By electrically energizing this magnet during operation, a much higher energization can be obtained than would be possible with a plain permanent magnet. There is, however, a permanent magnet core in this coil which acts to hold the polarized armature in its extreme operated position to allow it to be reliably locked when the armature of magnet N, drops.

Current flowing in the direction stated will cause the polarized magnet to be energized and shift polarized armature P, which causes contact X, to change over the connection for neutral magnet N, from wire 1RW, to wire 1NW. Magnet N, will then be connected to negative machine bus through

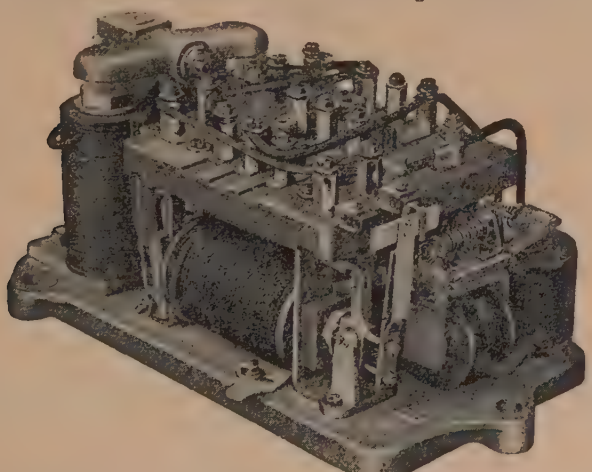


FIG. 6,633.—Union S. and S. Co. switch circuit controller. The coils, which are supplied with current through the circuit shown in fig. 6,632, are of high resistance, and therefore require but very little current for their energization. The controller makes it unnecessary to transmit current over individual *operating* wires from the tower. It also relieves all combination contacts of the interlocking machine, as well as relay contacts, from carrying currents of such magnitude as might be injurious.

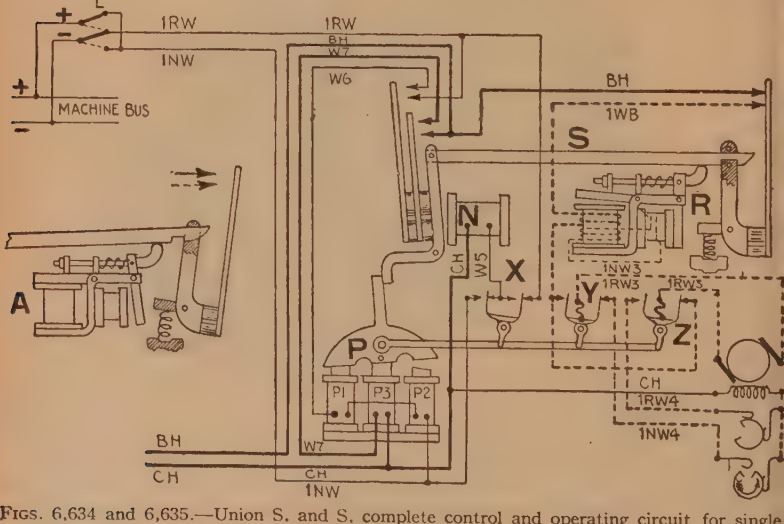
lever contact L, and to negative bus CH, at the magnet. This will obviously result in its de-energization and when the armature drops, polarized armature P, will be locked mechanically in its reverse position with its magnet de-energized.

The other two sets of contacts actuated by polarized armature P, will be so connected to the switch motor armature and field, that current will flow through the following path: positive bus BH, back contact of neutral magnet N, wire 1W8, primary coil of motor circuit breaker R, wire 1W9,

circuit controller finger Y, wire 1NW3, motor armature. wire 1RW3, circuit controller finger Z, wire 1RW4, motor cut out circuit controller contact, motor field, to negative bus CH.

The switch motor, in revolving, will cause the switch points to be unlocked, thrown and locked in the reverse position, the final movement also resulting in the motor circuit being opened at the motor cut out circuit controller.

It will be noted that before current can pass through the switch motor and cause reversal of the switch movement, the neutral magnet N, must be de-energized, this in turn causing polarized magnet P, to be de-energized. Thus the energization of these magnets is momentary and the amount of power consumed is negligible.



FIGS. 6,634 and 6,635.—Union S. and S. complete control and operating circuit for single switch.

The movement of the switch from reverse to normal is accomplished by the leverman moving the lever to a corresponding position, thus completing the circuit shown in full lines at L. The current will pass through contact L, wire 1NW, circuit controller X, wire W5, neutral magnet N, and to negative bus CH.

While magnet N, is energized the circuit for polar magnet P, will again be completed, but in such a way that current will pass through coils P1 and

P2, in a reverse direction to that previously described. This will cause the polarized armature to be reversed in position which in turn will actuate circuit controller springs X, causing neutral magnet N, to be de-energized, since it will again have both sides connected to negative bus, because wire 1RW, is connected to negative at the interlocking machine.

Contacts Y and Z, actuated by polarized armature P, will cause current to flow through the motor armature in a direction opposite to that when the switch movement traveled from normal to reverse. Contact will again be broken at the motor cut out circuit controller when the switch points have been moved over and locked. The controller springs will then be in the same position as shown in fig. 6,635.

As soon as the motor starts to unlock the switch, the motor cut out circuit controller contacts are shifted to the middle position and remain there until the final locking of the switch reversed, when they are shifted to the extreme reversed position.

The reason for the motor cut out circuit controller maintaining both circuits closed in the middle position during the entire transit of the switch is to allow for reversal of the switch by the lever at any time during transit if desirable, so as to repeatedly attempt to crush snow or ice which might prevent the switch point being forced against the stock rail and locked in that position.

The automatic overload circuit breaker R, is worked on very much the same principle as the overload circuit breakers on power switchboards, except that it is made slow releasing to prevent the possibility of the heavy starting current causing the circuit to be opened at each operation.

If an ordinary circuit breaker were employed, adjusted to open for a heavy current, the momentary current above mentioned would trip the breaker every time the motor started.

If this breaker open up due to high current for an excessive length of time, it can be restored by throwing the interlocking machine lever to its opposite indication position. In doing this, the neutral armature is again attracted, the hook engages the back contact member and upon subsequent de-energization of the neutral magnet the circuit breaker will be reset for another movement of the switch.

By the use of this circuit breaker, it is often possible to crush such objects as snow or a piece of coal lodged between the stock rail and the switch points, even though this may require a dozen operations of the switch. Each time the switch fails to complete its stroke the breaker will go out and will then be reset by moving the lever to the other indication position, avoiding the necessity of going to the back of the machine to renew fuses.

Switch Indication.—The operation of the switch indication circuit is shown in fig. 6,636. Contacts of the switch circuit controller operate only after the switch operating mechanism has completed the stroke of the points and locked them in place.

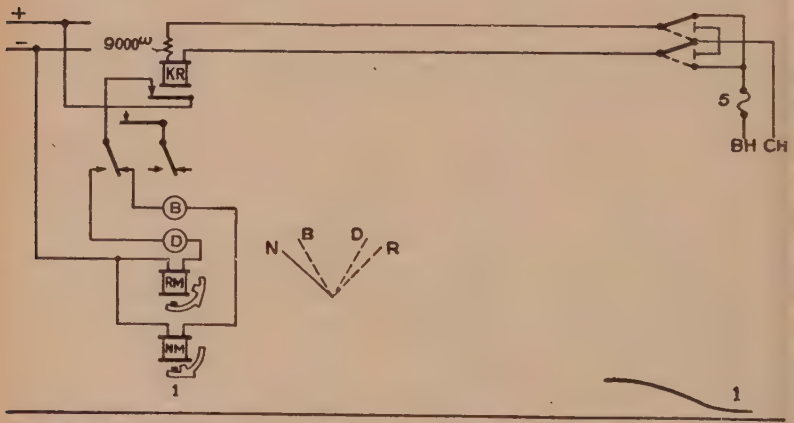


FIG. 6,636.—Switch indication circuit. Two magnets are ordinarily applied to the interlocking machine for the joint indication and detector control of lever movements. These magnets are marked NM, for the normal position and RM, for the reverse position of the lever and switch. The B, and D, lever contacts are mounted on the quick switch previously mentioned, which is so actuated by means of a toggle joint that it snaps over to the position indicated at the last part of the lever movement to the preceding normal or reverse position. This provides a check of the coincidence in position of the lever and the switch movement. Should the switch lever be reversed and the switch and lock mechanism function properly throwing over the points and locking the switch, the pole changer at the right will assume its alternate position, causing the polarized relay KR, to pick up in the reverse direction. Since the lever has been thrown over to the position marked D, indication magnet RM, will be energized, this picking up the dog from engagement with its segment and allowing the lever movement to be continued to the reverse position, which will release the mechanical locking so that a signal may be cleared. Provision is made in the circuit controller actuated by the switch and lock movement for the contacts here shown closed, to be opened at the first movement of the locking bar tending to unlock the switch points. A shunt between the two wires leading to the KR, relay is established at this time and maintained throughout the unlocking, throwing and locking of the switch points and until the last part of the locking stroke, when the pole changer will complete its movement and pick up the KR, relay in the reverse direction, as previously described. The movement from reverse to normal can now be easily traced.

NOTE.—In fig. 6,636 it should be noted that the KR, relay is at all times under the control of the switch, and that the unlocking of the switch by any means whatsoever will cause the KR, relay neutral contacts to open and remain open until the switch points are again fully closed and locked.

These contacts are connected so as to act as a pole changer. Two wires lead from this pole changer to a polarized relay, KR, in the station. A 9,000 ohm resistor is connected in series with this relay when the voltage is 110.

It is obvious that a low voltage polarized *d.c.* relay or a 110 volt three position *a.c.* relay may be substituted for the relay shown in fig. 6,636. The KR, relay functions not only in connection with the switch indication, but also in the SS, selection of signal control circuits. Any number of switches operated by a single lever can be made to indicate their position by means of a single KR, relay as shown for a crossover in fig. 6,637.

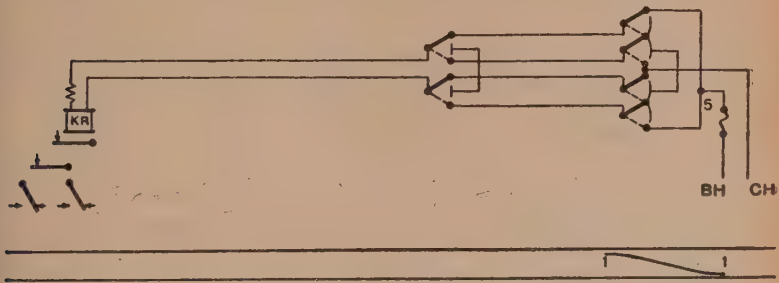


FIG. 6,637.—Indication circuit for cross over.

Section Locking.—Section or detector locking *has practically superseded the older form of switch protection, mechanical detector bars,* used before track circuits were available for preventing the unlocking and moving of switch points when a car was at the switch.

The increased protection gained by the use of section locking, both in the greater extent of track covered and the preliminary locking of the lever against movement, combine with the desirability of eliminating needless load and questionable operation under certain conditions, to remove the detector bar from further consideration. The combination of switch indication and section locking is shown in fig. 6,638.

The NX, and RY, contacts functioning in conjunction with the B and D contacts, provide for the alternate energization of the normal and reverse lever lock or indication magnets in such a way as to secure section or

detector locking when moving the lever from either of its extreme positions and indication locking when it is approaching the opposite extreme position, *i.e.*, at the indication point B or D.

A latch contact is provided in the section locking circuit for the sake of battery economy. This circuit breaks through either ordinary track relays TR, or their repeaters TP, or such relays as may be installed for sectional route locking. Approach and route locking may be added with equal facility.

Signal Control.—The control circuit for a single arm signal R2

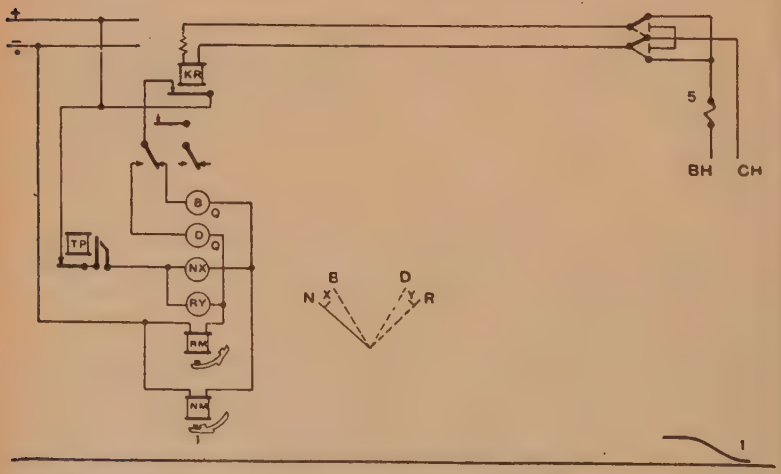


FIG. 6,638.—Combination of switch indcation and section locking.

is shown in fig. 6,639. In fig. 6,640 will be seen an enlargement of the circuit shown in fig. 6,639 to take care of signal RB2. Since only one of the two signals shown can be cleared at a time there is no necessity in this system for a separate lever to be used for each blade.

It will be noted that both sides of the circuit for both blades are broken through the signal lever contacts and selected through No. 1, switch lever

contacts. A further enlargement of the signal control scheme is shown in fig. 6,641. It is practicable to control all four blades by one lever No. 2. A slight variation is made in the circuits from those previously described to indicate that by the inter-control of two blades through circuit breaker contacts closed only when the signals indicate stop, one wire between the signal and the tower can be eliminated.

Signal Indication.—The indication circuits for signals in the electric interlocking system embody the same simplicity

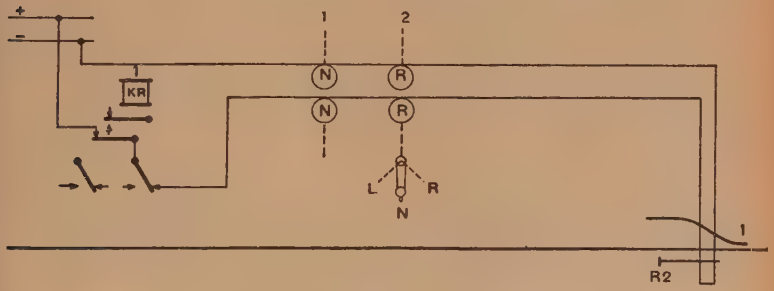


FIG. 6,639.—Signal control circuit. This consists of simply two wires extending from the signal to the interlocking machine, where both are broken through R, contacts on the signal lever and the proper contacts on the switch lever or levers concerned. This circuit is also carried through both neutral and polar contacts of KR, switch indication relays for all switches, movement over which is governed by the signal in question. Current for the signal motor is supplied from the bus mains through contacts of a control relay or signal hold clear device.

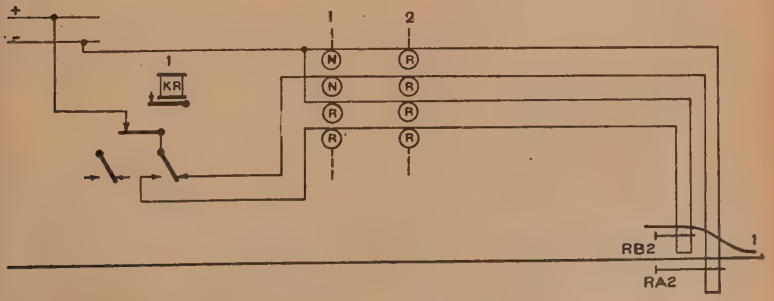


FIG. 6,640.—Signal control circuit for converging routes.

which is characteristic of the signal control circuits, as will be noted by reference to figs. 6,642 and 6,643.

Since the indication magnet should be energized only when all blades controlled by a signal lever indicate stop, the circuit controller contacts

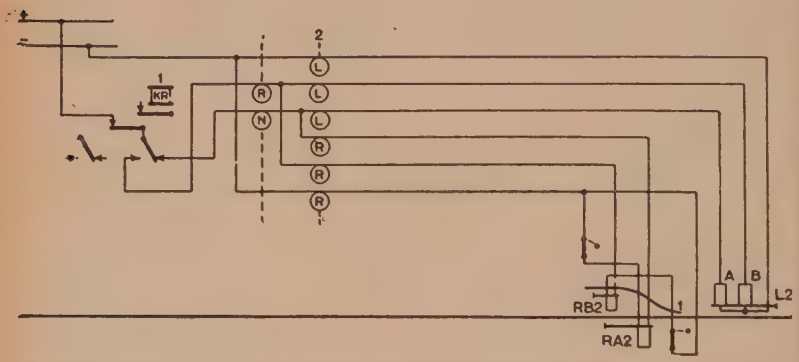


FIG. 6,641.—Signal control circuit for converging and diverging routes.

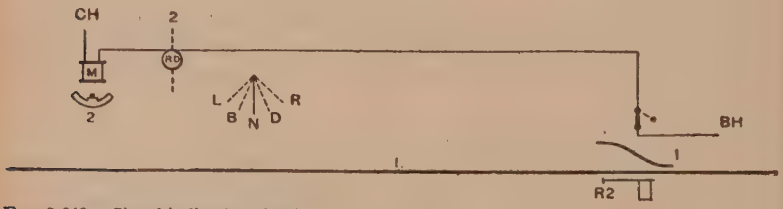


FIG. 6,642.—Signal indication circuit.

actuated by these blades are connected in series. The circuit is also broken through LB, and RD, contacts on the signal lever, connected in multiple.

Alternating Current Electric Interlocking.—Wherever a reliable source of *a.c.* power is available, an *a.c.* interlocking system has the following advantages over one using *d.c.*:

1. The power equipment is simplified.

2. Power losses between source of supply and interlocking units operated are reduced to a minimum.

3. *A.c.* track circuits insure maximum safety and economy.

Fig. 6,644 shows the scheme of *a.c.* power supply. Track circuits in *a.c.* interlocking may be supplied from the same mains that supply the units just mentioned. Signal lights may in either case be controlled over a separate wire in order that this circuit can be opened during the daytime if desired.

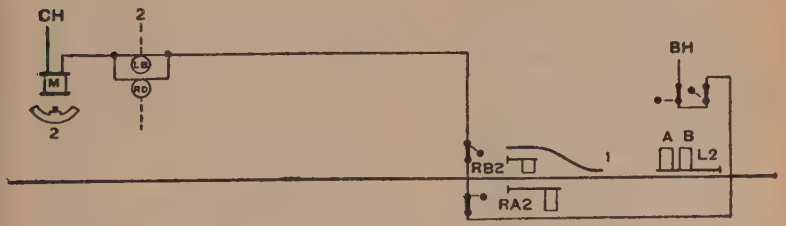


Fig. 6,643.—Signal indication circuit for opposing signals.

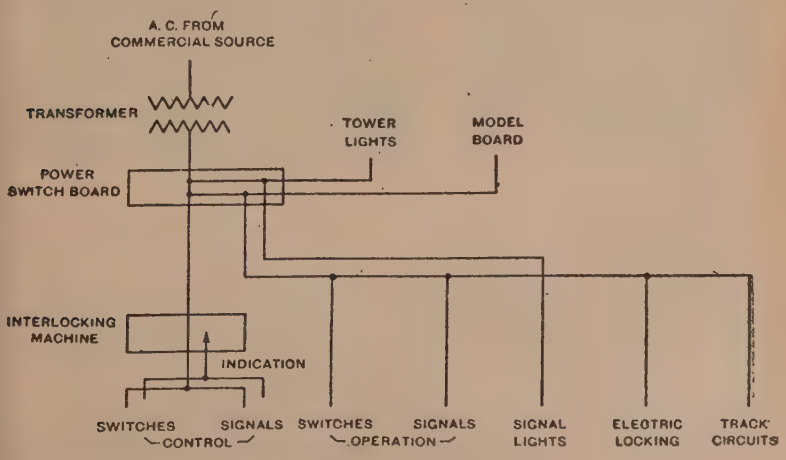
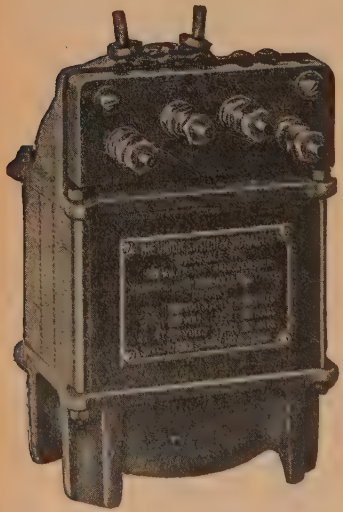


Fig. 6,644.—Diagram of power supply; *a.c.* interlocking.

Track Circuits.—The *a.c.* track circuit consists of a small air cooled track transformer of capacity ranging from 25 to 500 volt amperes, depending upon the circuit, a reactor or resistor and an *a.c.* relay, with the rails and wires connecting the two.



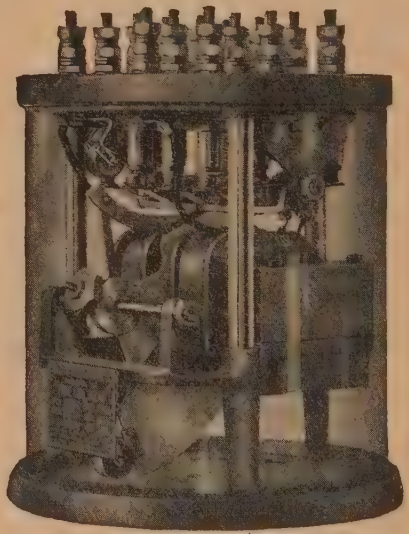


FIG. 6,645.—Track transformer.

FIG. 6,646.—Vane type relay.

Interlocking Machine.—Energy is taken through the switch board and interlocking machine to supply control circuits for switches and signals. *A.c.* is also received at the machine to indicate the position of the units outside.

The interlocking machine shown in figs. 6,619 and 6,620, and described in the section on *d.c.* interlocking, beginning on page 3,957, functions in

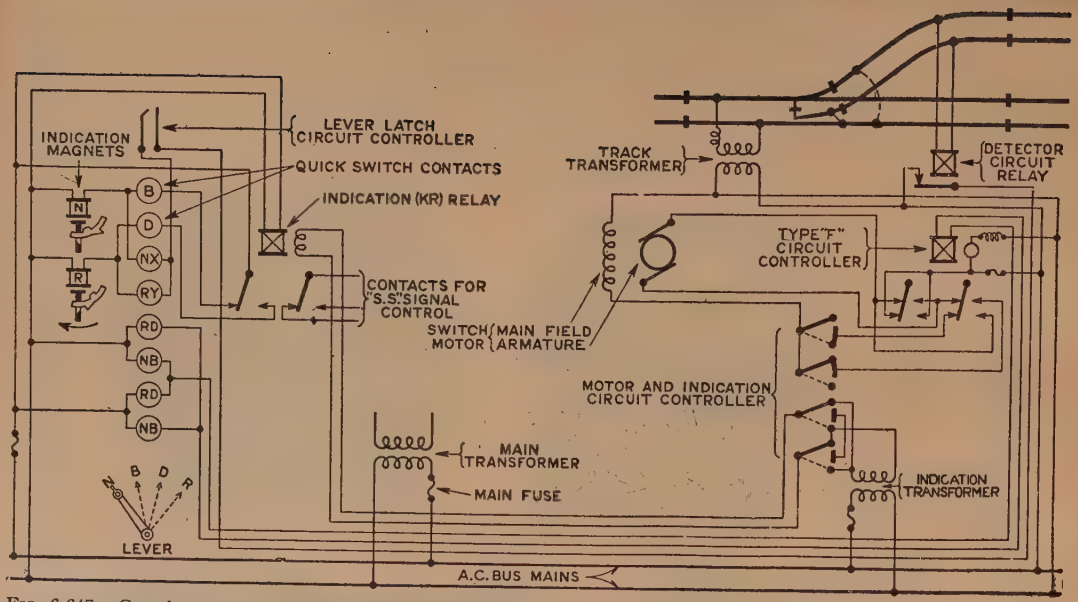


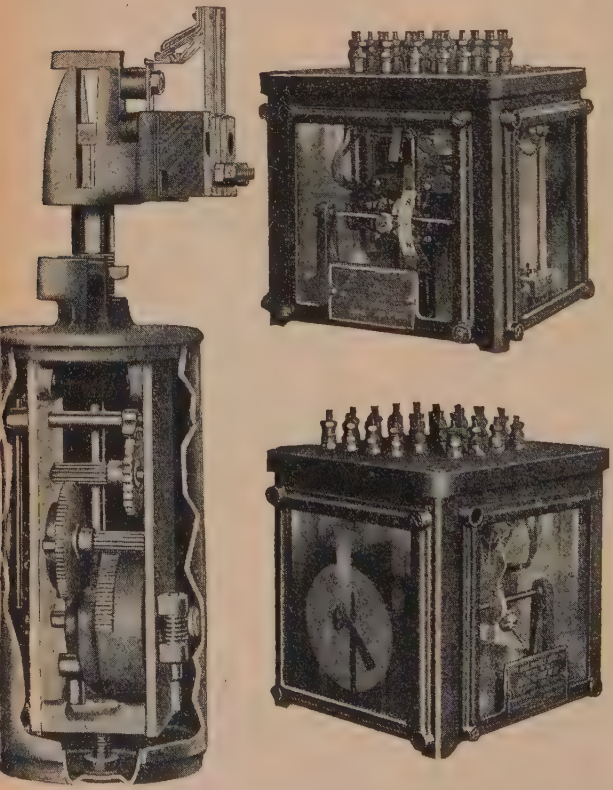
FIG. 6,647.—Complete control, operating and indication circuits for single switch; *a.c.* interlocking.

the same way and possesses the same safeguards for traffic on alternating as on direct current. The only difference in this machine is in the detail construction of the indication and lock magnets.

Controller.—The switch controller used in *a.c.* interlocking is similar to the corresponding device used in *d.c.* interlocking, except that it is not arranged for normal

de-energization, nor does it incorporate an automatic circuit breaker for opening up the motor circuit should the switch be blocked. Any dangerous load upon the *a.c.* switch motor, will be taken care of by the blowing of a fuse in the motor circuit.

Signals.—While necessarily differing electrically, these signals all agree in mechanical construction in general with their *d.c.* prototypes, and any one or all of them can be applied to *a.c.* interlocking. Light signals of the position or color type can also be applied.



FIGS. 6,649 and 6,650.—*A.c.* tower indicators. They are similar to standard relays, but with indicator blades or discs actuated by the armature. The position of the blade or disc indicates whether the track is occupied. The tower indicators may be equipped with contacts forming a part of the approach and route locking circuits. In some instances light type indicators have been substituted for those of the relay type.

FIG. 6,648.—Union style TP. clockwork time release. This release enforces a time interval between the preliminary operation of a lever on a power interlocking machine and the completion of its stroke

Tower Indicators.—It is desirable from a standpoint of ficient operation that *the leverman be informed concerning t location of trains both approaching the interlocking and within home signal limits.*

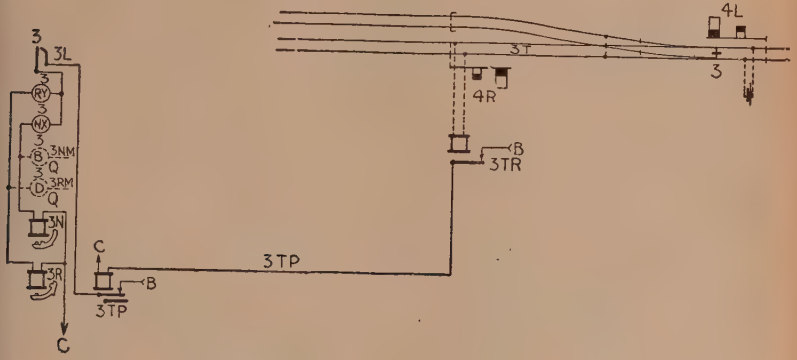


FIG. 6,651.—Section locking circuit.

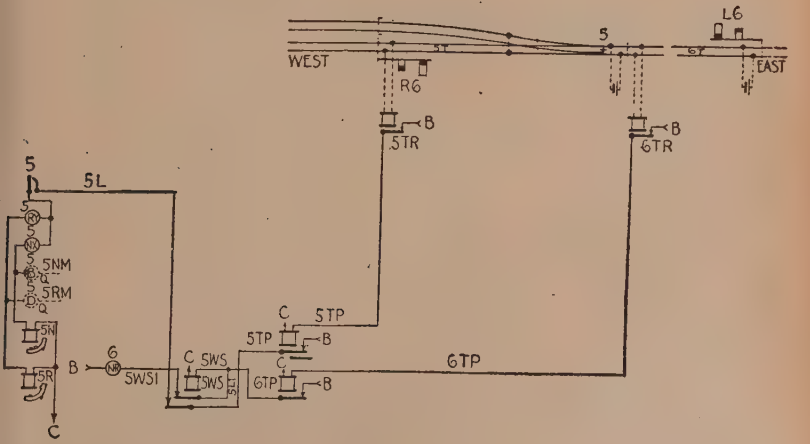


FIG. 6,652.—Sectional route locking circuit.

One means used to show track occupancy is the lever light described as a part of the interlocking machine. Another means is the tower indicator. Figs. 6,649 and 6,650 show *a.c.* type tower indicators.

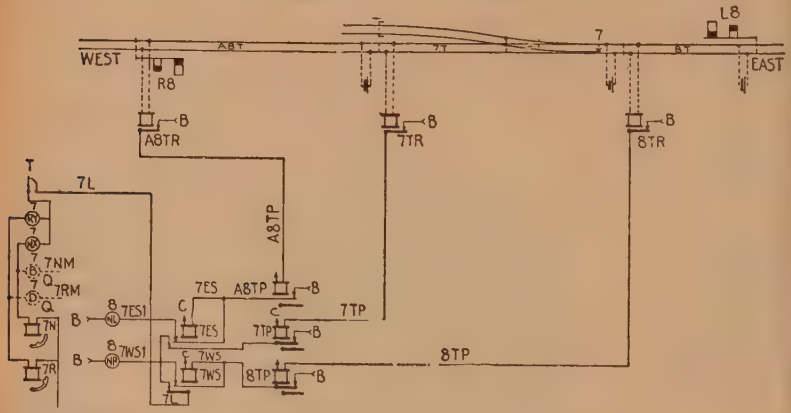


FIG. 6,653.—Sectional route locking circuit.

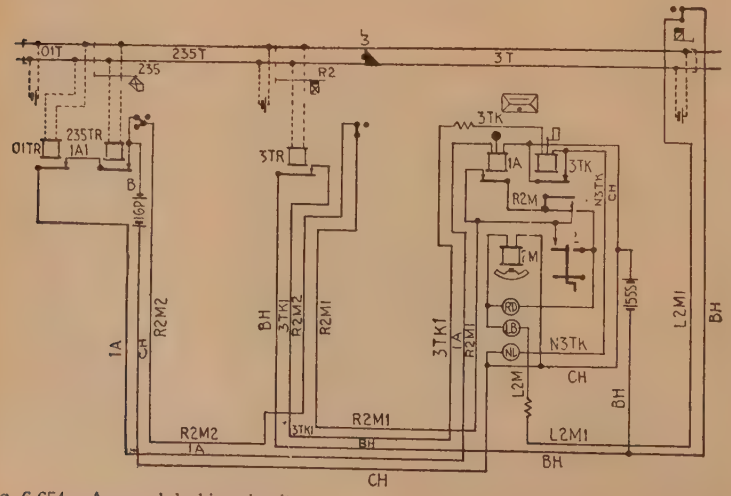
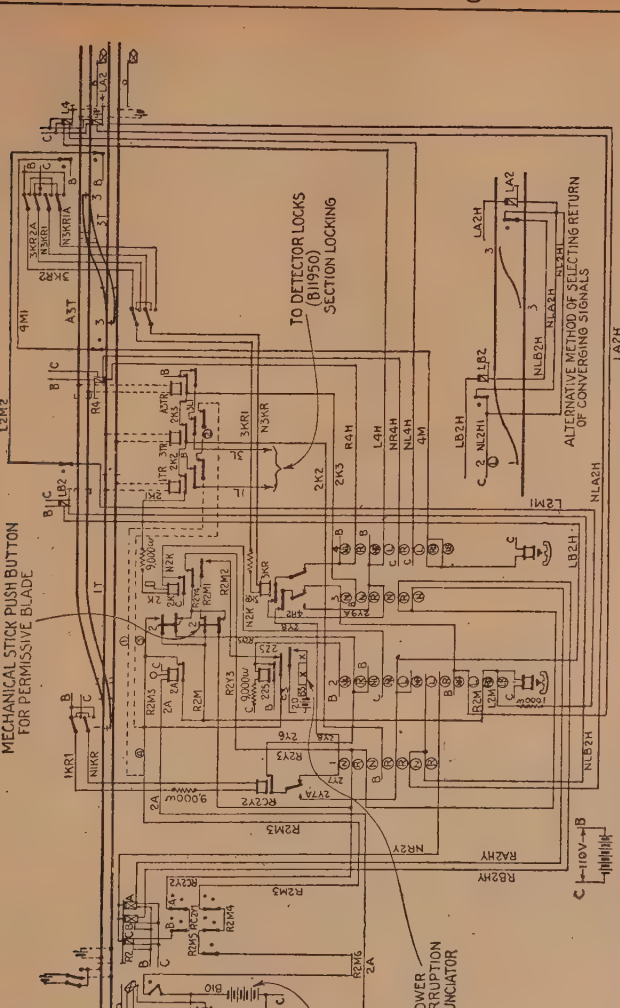


FIG. 6,654.—Approach locking circuit.



FIGS. 6,655 and 6,656.—Circuits for Union S. & S. Co. type F. *d.c.* electric interlocking, with approach, route and section locking.

Time Releases.—If all trains passing through an interlocking plant were to continue on the route first lined up for them by the leverman, and if there were no failures of track or other circuits affecting the automatic locking of the plant, there would be no necessity for time releases, but since it is at times necessary to change a lineup, due either to a misunderstanding on the part of the leverman, or to a change in other conditions, which has made such action desirable, a device which will allow this to be done safely is necessary. A time release is a *mechanical device for securing this result.*

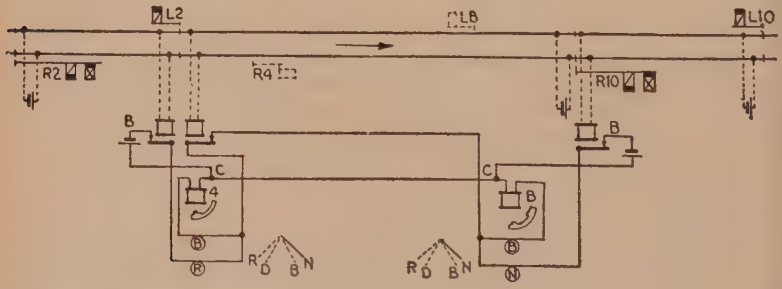


FIG. 6,657.—Check locking circuit.

Two types of time releases are in ordinary use. The mercury time release is intended for direct connection to the lever in the interlocking machine and functions coincidently with lever movement. It is carried on the plate which supports the usual indication or lock magnets, and is operated from the lever shaft.

The clock work time release is usually operated by hand. It has a graduated dial and clock hand which indicates at all times the amount of time elapsed after it has been released. This release may be set so as to provide any time interval up to four minutes.

Automatic Electric Control.—It is not sufficient that the leverman be kept informed concerning the location of trains approaching a plant and within home signal limits, but his

hands must be tied so that he cannot take any action which might create a hazard in connection with train movement. This is what automatic electric control does.

TEST QUESTIONS

1. *What is understood by the term "electric interlocking"?*
2. *Name the elements comprising an electric interlocking system.*
3. *Give the methods of power supply.*
4. *How is the power distributed?*
5. *What constitutes the heaviest momentary load on the battery?*
6. *How is power obtained for signal lighting?*
7. *Describe electric locking.*

NOTE.—***"SS" Scheme of Control.*** The continuous check of the position of each and every switch over which a signal governs train movement, by carrying the control circuit of that signal through contacts on the KR relays for the switches concerned, is known as the "SS" system or scheme of signal control. This control is characteristically a part of Union type "F" electric as well as of electro-pneumatic interlocking.

NOTE.—The "SS" scheme assures: 1, that should a switch not respond to a lever movement and through some fault or series of faults the lever movement be completed, subsequent operation of any signal lever cannot cause a signal to clear; 2, that should a switch be accidentally or maliciously changed in position, any signal cleared for train movement over the switch will immediately assume its stop position, nor can any signal be cleared until the switch is locked in a position coinciding with that of its controlling lever.

NOTE.—***The "SS" control of signals provides:*** that *every* signal, high and dwarf, be directly controlled by *every* switch and derail, both facing and trailing point, over which it governs train movement, and for every minute of the time. In other words, this scheme of control is *complete*. That the signals governing the main track movements be controlled not only by the switch of a turnout, but by the derail which protects against side-wiping. Similar protection is provided at crossovers.

8. *How is concentration of control obtained in electric locking?*
9. *Describe the lever manipulation of the interlocking machine.*
10. *What are the checks on lever movement?*
11. *How are the contact rollers mounted?*
12. *How are the lever lights mounted?*
13. *What is the sequence of operation in moving a switch?*
14. *Draw a diagram showing a switch control circuit.*
15. *How does a controller work?*
16. *Draw a diagram of the switch indication circuit.*
17. *When do the contacts of the switch circuit controller operate?*
18. *What are the names given to section locking?*
19. *Draw diagrams showing control circuit for a single arm signal.*
20. *Draw a diagram showing a signal indication circuit.*
21. *What advantages has* a.c. *over* d.c. *for electric interlocking?*
22. *Draw diagrams showing the scheme of* a.c. *power supply.*
23. *Of what does the track circuit consist?*
24. *What duty is performed by tower indicators?*
25. *What is a time release?*
26. *Describe automatic electric control.*

CHAPTER 149

Electro-Pneumatic Interlocking

The electro-pneumatic system derives its name from the fact that *compressed air is employed to perform the work;* that is, the shifting of the switches and signals, and electricity is used to *control* or *direct* the performance of the work; that is, the admission and discharge of pressure to and from the cylinders by which the work is performed.

The use in the electro-pneumatic system of simple cylinders for switch and signal operation compared with the use of electric motors for like duty in purely electric systems gives to the electro-pneumatic system the advantages of simplicity, accessibility and durability.

There is also the advantage arising from the ready control, in a simple and effective way, of the energy (the compressed air) which is employed without destructive effect either upon the devices controlling it or upon the appliances utilizing it.

The system consists of the following elements:

1. A source of compressed air supply of approximately 75 lbs. per sq. in.

2. A source of current supply of approximately 12 volts.

3. An interlocking machine for controlling the operation of switches and signals.

4. Switch operating mechanisms with their controlling and indicating circuits.

5. Signal operating mechanisms with their controlling and indicating circuits. Auxiliary devices, of optional character, for performing special functions, such time locks, electric clockwork or manual emergency releases, indicators, annunciators, etc., can be installed as desired.

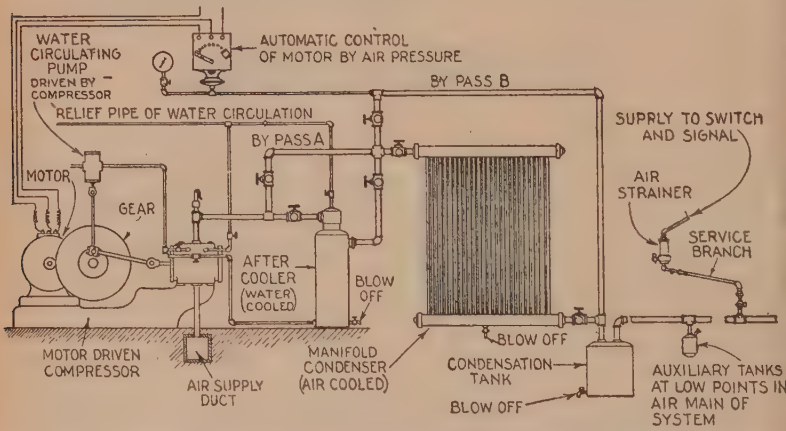


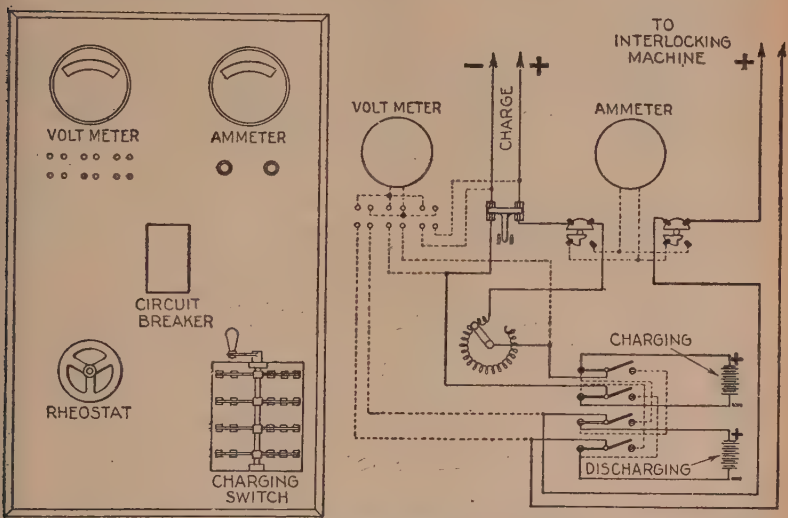
FIG. 6,658.—Diagram of typical air compressing, cooling and distributing system for electro-pneumatic interlocking

Compressed Air.—This embraces, preferably, two compressors, one as a relay to the other, which may be driven by electric, steam or other available power, as local conditions may justify.

Frequently, especially at terminals, a source of compressed air supply exists, or is required, for other purposes, such as cleaning of cars, operation of tools, etc. This same supply may be used for the interlocking system, with no appreciable reduction in the volume of air available for the purpose it was originally provided for, since the interlocking system requires but a comparatively small amount.

At interlocking sites where no supply of compressed air exists for other than interlocking purposes, there is usually available a source of *d.c.* or *a.c.* which may be utilized for the operation of air compressors.

Fig. 6,658 shows diagrammatically the appliances used for the compression, cooling and distribution of air in large electro-pneumatic interlockings. A two-inch air main extending throughout the interlocked territory is ample for distribution of the pressure to the various cylinders of the system with no appreciable loss due to drop therein. Branch pipes from the main air pipe are usually of ¾ in. diameter, reducing at the switches and signals to a diameter of ½ in.



FIGS. 6,659 and 6,660.—Typical switch board equipment and circuits for electro-pneumatic interlocking charging plant.

Electricity.—For the control of the various appliances the *electric current may be taken from any reliable source.*

Such a source is generally already available. Usually *d.c.* is employed for all purposes through the medium of a 12 volt storage battery.

Electro-Pneumatic Interlocking Machine.—This machine is electro-pneumatic in name only, since *there is no compressed air used for any purpose within it.*

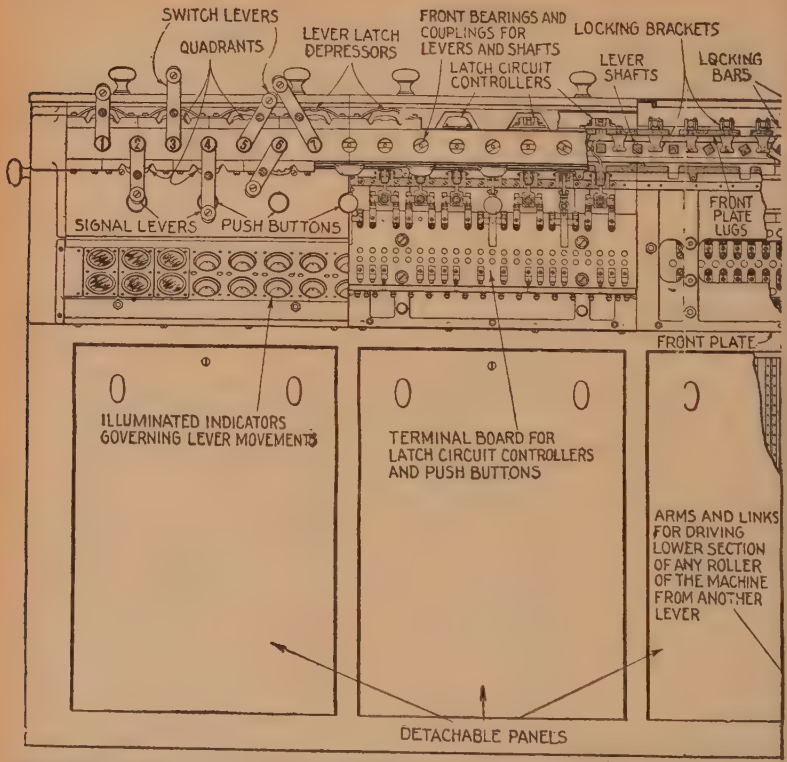


FIG. 6,661.—Union S. and S. Co. electro-pneumatic interlocking machine complete. Side view showing signal levers, terminal board, locking bars, quick switch, indication magnets, etc. This illustration is continued on page 3,995.

The machine consists of *miniature levers conveniently arranged in a common frame and adapted to the operation of a bank of mechanical locking similar in character to that employed in mechanical interlocking machines, but of diminutive design.*

Each lever in the machine also operates a plurality of electric contacts, and attached to each lever is one or more electric locks. The *mechanical locking* is provided to prevent the operation of levers which, if moved, would conflict in function with one or more other levers.

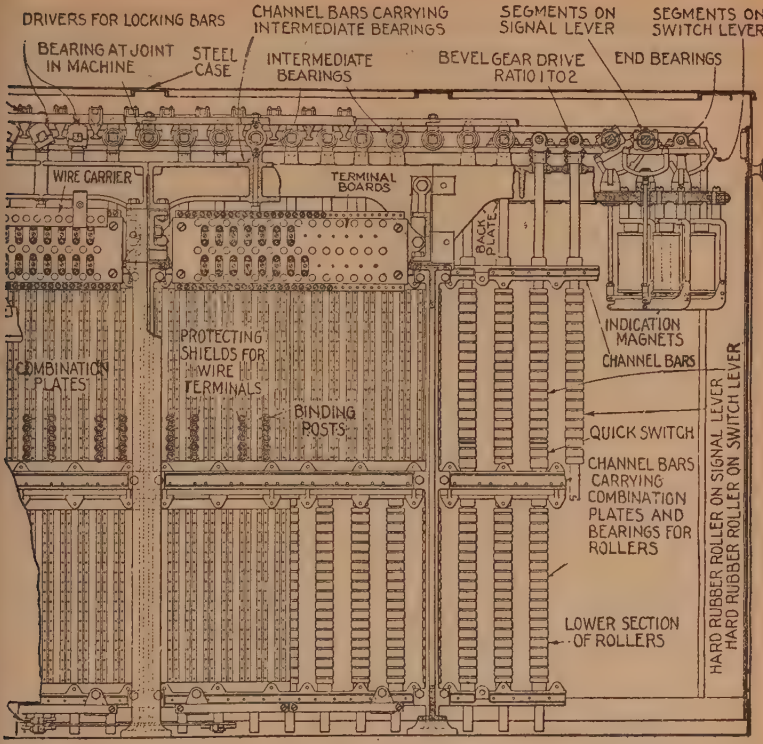
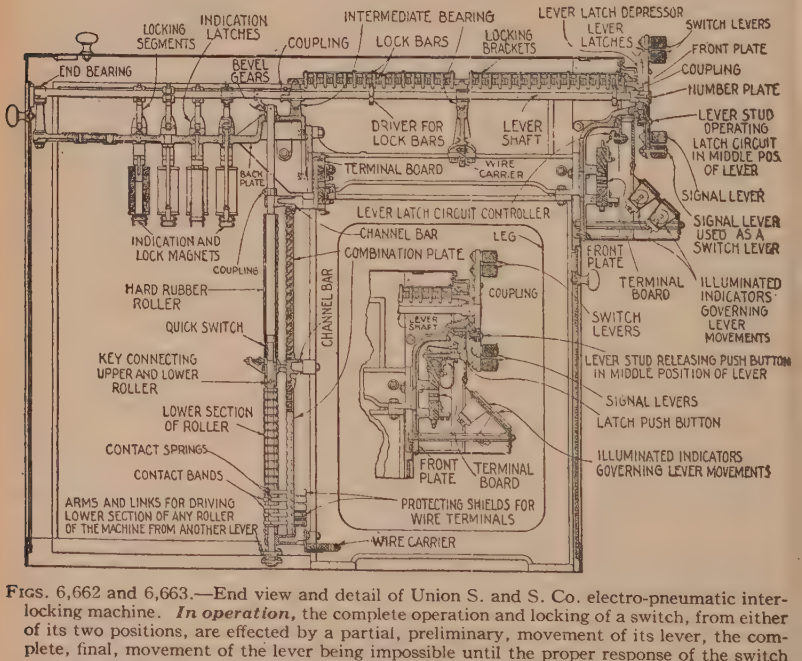


FIG. 6,661.—*Continued.* The above illustration is a continuation of fig. 6,661 on page 3,994.

The *contacts* control electric currents by which switches and signals are operated by the levers and are also used for opening and closing different circuits as required by the many combinations of lever positions.

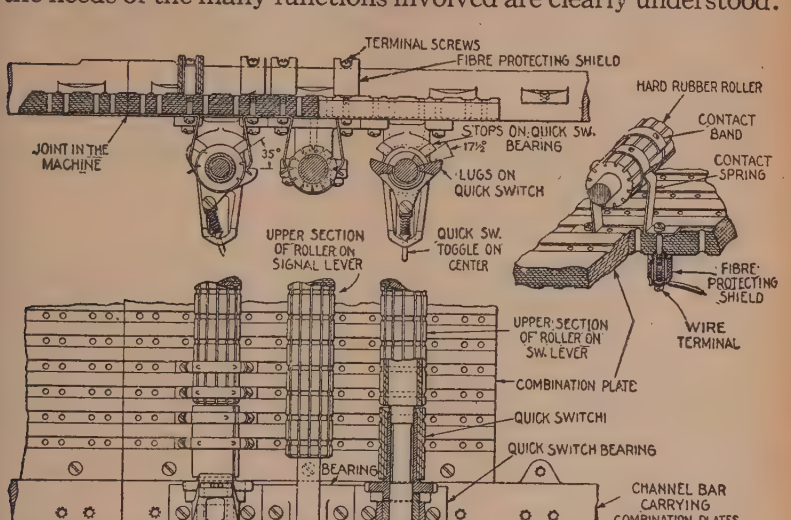
The *electric locks* are provided for restraining lever operation according to conditions remote from the machine when these are adverse to their safe operation, such as preventing final movement of levers until the operated unit has responded to the initial lever movement and preventing effective movement of switch levers by train action where detector track circuits are used in lieu of mechanical detector bars. Figs. 6,662 and 6,663 show end view and detail of the machine.

In the sections following, switch and signal operation from the machine and the inter-control between machine, switches, signals, and track detector circuits are dealt with in such a way



FIGS. 6,662 and 6,663.—End view and detail of Union S. and S. Co. electro-pneumatic interlocking machine. ***In operation,*** the complete operation and locking of a switch, from either of its two positions, are effected by a partial, preliminary, movement of its lever, the complete, final, movement of the lever being impossible until the proper response of the switch to the preliminary lever movement occurs. Two systems of circuits are employed for these purposes; one for effecting switch operation, and one for releasing the lever thereafter for its final movement; the latter being known as the indication system. The complete operation of a signal from stop to proceed is effected by a continuous, complete lever movement, but its operation from proceed to stop necessitates two movements of the lever; a preliminary movement for interrupting the power supply to the signal, and a final movement that can be made only when the signal so deprived of power, returns fully to the stop position. The operation of switches and signals thus involves the opening and closing of electric contacts during lever movement and at definite points in the lever's throw. The control of lever movement by switch and signal position, which also embraces this contact control, necessitates the use of electric locks upon the machine which permit or prevent lever operations according to the energized or de-energized state of their magnets. Control of these locks is not restricted solely to switch and signal operation, train action being also at times a factor in it.

that the requirements of the interlocking machine for meeting the needs of the many functions involved are clearly understood.



FIGS. 6,664 to 6,666.—Details showing part of combination plate and contact rollers of Union S. and S. Co. electro-pneumatic interlocking machine. The panels or plates which support the contacting system are of moulded insulating material To these plates the contacting springs are secured by brass screws which pass through them and into square brass nuts by which the screw and spring are secured. These nuts, being square, and set into vertical grooves, cut in the rear of the plate, are non-turning, while the contact springs lying in similar grooves cut in the front of the plate are likewise held against turning by a single screw through each. The nut by which the screw is secured is of special length where wire connection to a contact spring is to be made, and that portion of the nut which extends beyond the screw is equipped with a second screw and washer for securing the external wire connection. Over the terminal posts thus formed, a tube of insulating material is placed; the external wire connection being in a notch cut in the outer end of this tube, and the wire is secured to the post by the screw.

NOTE.—***The front plate*** of the electro-pneumatic machine is constructed to recede from the plate in which the levers operate and thus to form a compartment under the levers for the housing of the various lamps and contacting devices that are frequently made a feature of lever manipulation in this system. The lamps serve as indicators and inform the

Switch Operation and Control.—Each set of switch and frog points embraced in the track system is operated by a switch and lock movement, a purely mechanical device designed first to unlock the switch, then shift it and relock it in its new position.

The switch and lock movement is operated by direct action of the piston of a double acting cylinder, of which the admission and exhaust are controlled by a slide valve mounted upon the cylinder.

NOTE.—Union S. and S. Co. signal and switch levers same for electric, and electro-pneumatic interlocking; see figs. 6,625 and 6,629. Assuming that a signal lever has been operated to permit a train to move over the switch, the switch lever shown is mechanically locked in the position it assumes, and this fact secures the lever, the switch valve, the switch, the indicating circuits and the polarized indicating relay in the following respective conditions: 1, lever normal; 2, normal switch valve magnet energized; 3, slide valve held and locked positively in normal position by air pressure; 4, the switch resting without pressure in its cylinder in its normal position and mechanically locked there; 5, the two indicating wires maintained at different voltages of a given polarity; 6, polarized indicating relay energized to close its neutral contacts and its normal polar contacts; 7, source of electric current including the neutral contact and one of the closed polar contacts that constitutes parts of a circuit which includes also the open contacts of the quick switch and the helix of the normal indication magnet; 8, second circuit employing the neutral contact of the polarized indicating relay and the other one of the closed polar contacts as the source of current supply to those contacts actuated by signal levers that primarily operate the one or more signals that govern train movements over the switch. Obviously under this assumption, the switch lever cannot be moved until the signal lever is placed normal and the signal is in the stop position.*

*NOTE.—***The operation** of the switch by other means than its lever as by the malicious or accidental manipulation of its operating mechanism, will be first accompanied by an interruption of the electric energy in the indicating wires and then a shunting of these wires against influence from foreign sources. This produces a de-energization of the indicating relay, the effect of which is to cause it immediately to cut off the electrical energy, through its contacts by which each signal, governing movements over the switch, is controlled, and thereby to place at stop any such signal as may at the time be in the proceed position, or should all of them be in the stop position at the time, prevent the operation to proceed of any such signal.

NOTE—*Continued.*

operator when a lever may or may not be moved. The usual contacting mechanism that is contained in this compartment has several functions; first, the control of switch lever locks by the catch rods of the levers so as normally to retain the locks upon open circuit, as a matter of current economy solely; and, second, the retention of these locks positively separated, during lever movements between indicating positions from any possible supply of current energy to them save through the proper channels of the indicating system. Behind each signal lever is a "latching push" button, the action of which when depressed is to operate a calling on arm when the usual signal does not respond to the lever's movement by reason of the semi-automatic control of the signal and the presence of a train upon the track it governs. The depression of the button, in such cases, mechanically latches it, depressed, and in consequence, the circuit of the calling on arm is closed until the latch is released. This release occurs by the partial restoration of the signal lever to normal.

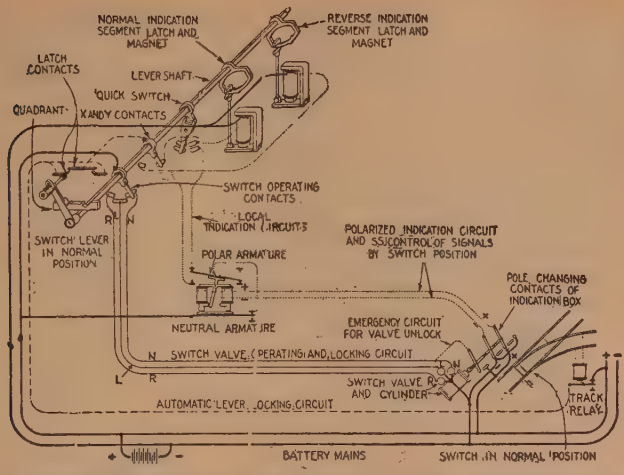


FIG. 6,667.—Diagram of complete ***switch control,*** indication and locking circuits; ***switch and lever in the normal position.*** The indicating system is in corresponding condition and the switch is unoccupied by trains and its lever free to be operated.

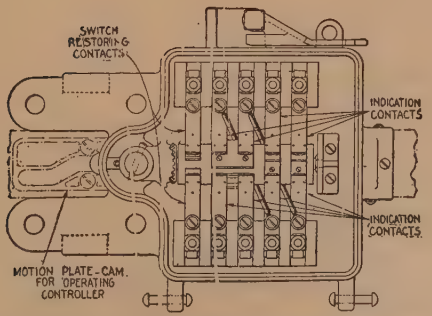


FIG. 6,668.—Union S. and S. Co. pole changing indication circuit controller.

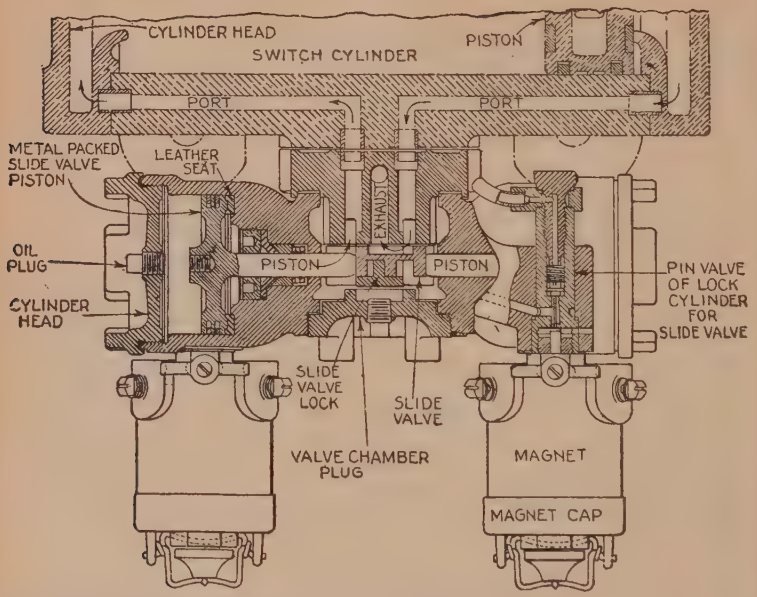


FIG. 6,669.—Union S. and S. Co. switch valve, magnets and switch cylinder. ***It comprises*** a slide valve that is shifted by two opposed, miniature pistons actuated by air pressure which are controlled from the switch lever through the medium of two electro-magnets, one upon each cylinder. Through the operation of the slide valve, air is admitted directly from the air main to one end of the switch cylinder, while the pressure within the other end of the cylinder is simultaneously liberated to atmosphere. Means are also provided for mechanically locking the slide valve after each operation of the switch and upon completion of the final movement of the switch lever thereafter. Not only does this final movement of the switch lever apply a positive lock to the slide valve, but after so locking the valve, it cuts off the air supply to the slide valve chamber, and hence to the switch cylinder. There are three electro-magnetically operated pin valves embraced in the shifting and locking of the slide valve by which the movements of pneumatic switch cylinder pistons are effected. One of the magnets of these valves is energized normally to retain air pressure constantly against one of the two miniature slide valve pistons, and hence, positively holds this valve in one of its two positions. One of the other magnets becomes energized as the first mentioned one becomes deenergized when the lever is shifted to cause switch reversal. The application of air pressure thus to the other miniature piston, simultaneously with the discharge of air from behind the first one, causes the slide valve to shift and thereby to reverse the piston of the switch cylinder. Such action of the slide valve, however, can occur only after the third magnet and pin valve have been actuated to unlock the valve and simultaneously to admit the pressure from the air main into the slide valve chamber. The energization of this third (lock) magnet occurs the instant the switch lever is shifted from either of its extreme positions, and hence the slide valve remains unlocked and the pressure remains within the slide valve chamber at all times save when the lever is in its completely normal or in its completely

The operation of the slide valve is effected by three electro-magnets, mounted on the valve, which are connected to the lever contacts of the machine by three individual wires. These are the *control wires*.

Safety Devices.—Failures of switches to respond to their levers *are indicated by the switch indication system*. Mounted on the switch and lock movement operating the switch points is a contacting device known as the *indication circuit controller*. Two wires between this controller and the polarized indicating relay for the corresponding switch serve for indicating purposes.

FIG. 6,669.—*Text continued.*

reversed position. Movements of switch levers into these extreme positions can occur only when switches and their levers coincide in position and when the switch is thus securely locked mechanically, and hence the locking of the slide valve and the release of air from the valve chamber can take place only after complete switch and lever operation have occurred and complete coincidence of position of both has been assured.

NOTE.—***Detector bars.*** When detector bars are made a feature of electro-pneumatic interlockings they operate continuously with the piston of the cylinder from the slide bar of the switch and lock movement. The first part of the piston's movement, employed primarily for unlocking the switch, is also employed for the elevation of the bar above rail level. A train standing upon or moving over a switch obviously prevents the elevation of the bar, and hence the unlocking and movement of the switch under trains. During that part of the piston's stroke that effects switch operation, the bar travels idly in its elevated position without material resistance; and during the final movement to lock the shifted switch the bar is depressed to its former position below rail level.

NOTE.—***Indication circuit controller.*** This device is mounted directly over the slide bar of the movement and is actuated positively thereby. The device comprises an oscillating drum of insulating material carrying contacting plates, which make and break electrical contacts with a system of flexible contacting fingers included in the circuits of the indicating system at predetermined points in the operation of the switch and lock movement as shown in fig. 6,668. Normally, a current flow is maintained through two contacts of this device in one direction, and through two of its other contacts in an opposite direction. This current, through two isolated conductors which extend to a polarized relay at the interlocking machine, maintains a normally active state of that relay to retain closed certain contacts and to retain open certain other contacts. Upon full reversal of the switch and lock movement a reversal of the flow of current is produced by reason of the changed relations then occurring between the contacting members of the indication circuit controller. The polarized relay is thus caused to reverse its influence upon its contacts and hence closes those contacts that formerly were open and opens those that were formerly closed. The contacts of the relay thus repeat the two positions of the switch and lock movement, and are therefore employed for controlling not only the normal and reverse indication magnet of switch levers during switch operation by simple local circuits, but are used also as a means wholly within the interlocking tower to obtain control of the current supply to every signal of the system by actual positions of each and every switch over which it governs.

These wires are separate and distinct from the control wires, thus completely isolating the indication system from the control system. These two wires energize a polarized relay at the machine in the tower and constitute the complete indication circuit without connection with the common return wire, so that crosses or grounds have no serious effect. This arrangement eliminates the necessity of providing complicated apparatus for preserving the integrity of the control and indication circuits.

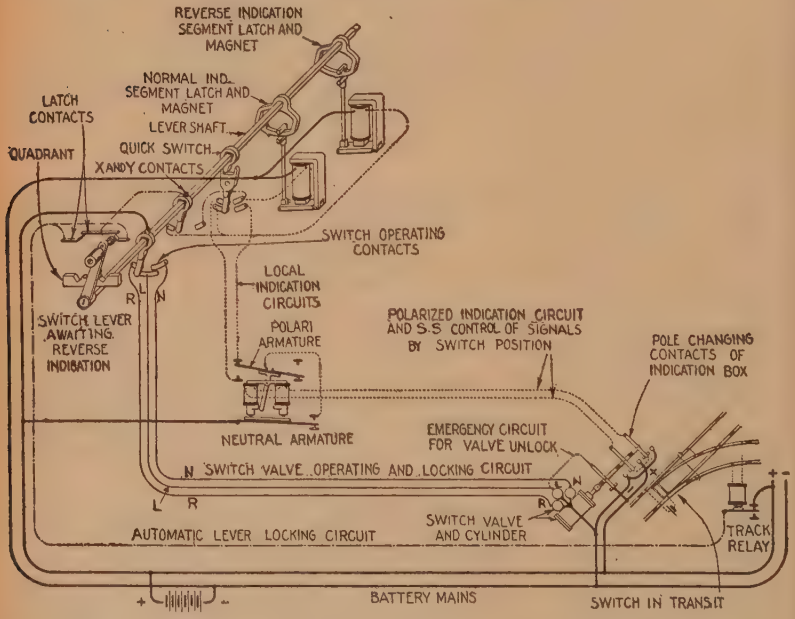


FIG. 6,670.—Diagram of complete ***switch control,*** indication and locking circuits; ***lever partly reversed, switch in transit.*** The lever is moved as far as the indicating segments and latches permit, the switch valve as having responded and the switch as responding, at mid-stroke. It shows the effect, the shunting of indicating wires, produced in the indicating system by the mechanical unlocking of the switch prior to and during its change of position.

Protection against crosses is obtained by the two indication wires and the polarized indication relay (without a common return wire) forming a complete circuit from positive battery through a contact of the indication pole changing circuit controller on the switch and lock movement, through one indication wire to, and thence through the coils of the indication relay

back over the second indication wire to another contact of the indication circuit controller and thence to the negative side of the battery.

Thus each switch lever embraces the use of a polarized relay that can respond to a current of one polarity only for one indication, and which

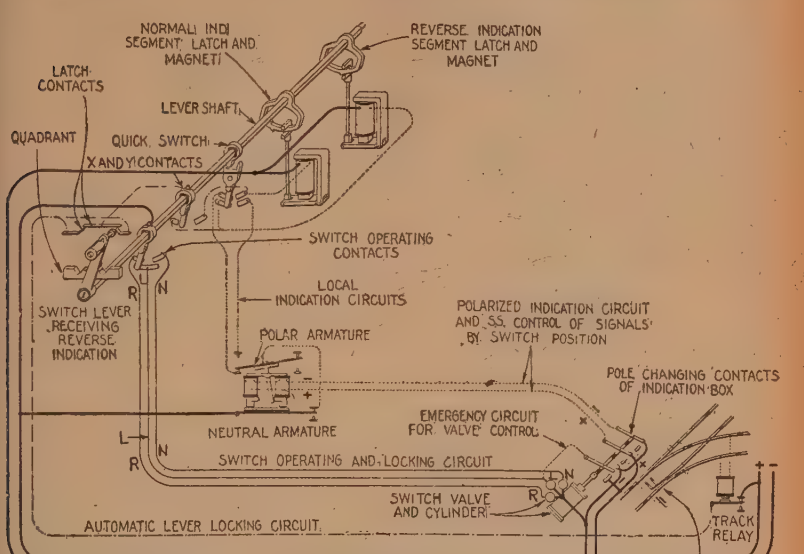


FIG. 6,671.—Diagram of complete ***switch control,*** indication and locking circuits; switch reversed, *lever about to receive the indication.* The switch having responded, the lever is released for final movement. The conditions of fig. 6,671 are here represented. When in ordinary operation the switch assumes a reversed position by virtue of a partial reversal of its lever, the indicating relay becomes again energized, but by current of a reversed polarity from that existing when the switch and lever were normal. The effect of this is to shift the polar contacts of the relay to establish current through the reverse indication magnet and the closed contacts of the quick switch, and thus to release the lever for final movement to its full reversed position. This final movement causes action of the quick switch again to open the circuit of the reverse indication magnet, and so to connect the normal indication magnet with the open polar contacts of the indicating relay as to prepare that magnet for its next indicating function, as shown in fig. 6,672.

requires a reversal of that current for another indication; the use of two conductors electrically separated from other wires of the system, which include in circuit the polarized relay; and a pole changing circuit controller contact

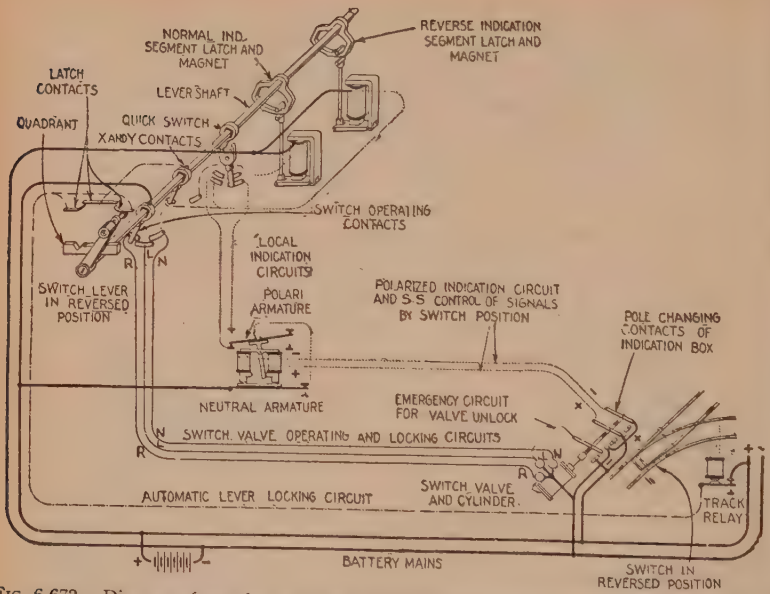


FIG. 6,672.—Diagram of complete ***switch control,*** indication and locking circuits; ***switch and lever reversed:*** this is the final position. During the movement of the lever to shift the switch from normal, the lower magnet, latches and segments alone are called into service; during a corresponding reverse operation of the lever and switch, the upper set of magnets, latches and segments alone are called into service. Preliminary to each lever movement, however, that magnet which lies idle during final lever movement, is in actual practice, actively controlled, by train action upon the switch, as an electric lock to the lever. While one magnet thus permits the use of a lever for effecting switch operation, the other one insures, during lever operation, a correct response of the switch before the final lever movement can be made, this final movement transferring that magnet which permitted it, to the duty of locking the lever automatically by train action, and simultaneously withdrawing the other magnet from that service and into the indicating service required for the next operation of the switch. This transfer of the magnet from one field of usefulness to another occurs at the completion of each full lever operation and is performed jointly by what is termed the *quick switch,* and by what are designated as X, and Y, springs of the contacting system.

NOTE.—***The control of the indication magnets*** by the quick switch, as shown in fig. 6,672, involves the use of but one magnet at a time for indicating purposes, and hence, leaves at all times one of the magnets free for other duties if desired. It is this fact that promoted the alternative use of each indication magnet for detector circuit switch lever locking by trains in the electro-pneumatic system. To render this effective, two contacts operated by the switch lever are employed, that are designated as X, and Y, contacts, for the purpose of throwing, alternatively, the indicating magnets into circuit with the contacts of a track relay that embraces the switch rails in its control. In this way, trains entering upon the switch cause that

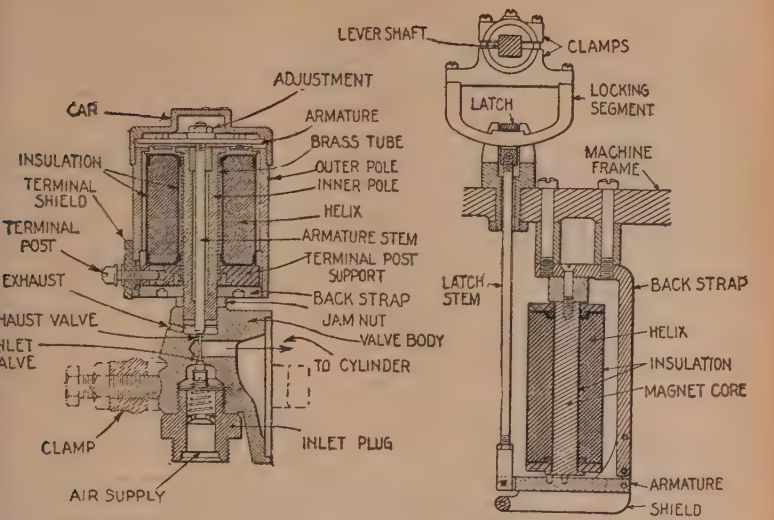


FIG. 6,673.—Union S. and S. pin valve and magnet which controls the pressure to and from the air cylinders. In signal operation it controls directly the pressure to and from the operating cylinder; in switch operation it is not so well adapted to this direct control because of the great volume of air required by switch cylinders and because, also, of the quicker action demanded of switches. For this service it is made to control a D, slide valve, through the medium of two miniature cylinders, the D, valve directly controlling the pressure to and from the switch cylinder.

FIG. 6,674.—Union S. and S. Co. indication or lock magnet on the interlocking machine for duty which does not include the control of air pressure.

NOTE—*Continued.*

one of the indicating magnets that was last used for switch indicating purposes to remain upon open circuit and therefore to prevent initial movements of the lever, until the train has passed clear of the switch. The locking circuit thus formed also passes through a contact that is acted upon jointly by both the catch rod and the lever, a contact closed as the catch rod is elevated to energize the lock, if the track be unoccupied, and which is opened again by the levers during its movements between its positions of engagement by the locks. This is done by the latch to economize in current energy when the lever is at rest in either the normal or the reversed position, and by the lever absolutely to disconnect both magnets from any possible current influence save that peculiar to the indicating system, as soon as the lever moves beyond the influence of the automatic track circuit control of levers and into that entirely separate field of control that embraces only the switch indicating system.

for each indication wire. This arrangement not only separates both conductors of the indicating system from the source of electrical energy during transit of the switch but, at the same time, establishes a shunt or short circuit between the indicating conductors.

Signal Operation and Control.—*Each signal of the system is operated by a single acting cylinder*, the admission of air to which is under the control of a pin valve and electro-magnet of similar construction to those employed on the valves used for switch operation.

Since gravity is employed to return signals to their stop position, double acting cylinders are not required in signal service.

The pin valve magnet (see fig. 6,673) is connected by wire with its operating lever in the interlocking machine and is energized only when the lever assumes one of its extreme reverse positions. When so energized, air is admitted to the cylinder and the signal moved to the proceed position. This movement of the signal opens a contact in a second circuit including an electric lock engaging the signal lever, thereby applying the lock to prevent complete return of the lever to its normal position. Its partial return, however, is permitted, a movement which causes the interruption of the signal circuit, and hence a return of the signal to the stop position.

Upon reaching the stop position the circuit including the lever lock is again established and the lock re-energized. This results in the release of the lever so that it may again be placed in its normal position.

Electro-pneumatic signals may be operated in either two or three positions, upper or lower quadrant, and giving right or left hand indications as desired. They may also be operated without change by lever only, by track circuit only, or by combination of the two.

Auxiliary Features.—The elements already described are what may be termed *essentials* of the system. Additional special features are frequently desired or required by the peculiarities of the local conditions under which the system is to operate. These features are:

1. Semi-automatic control of signals;

2. Calling on arms;
3. Section locking;
4. Approach locking;
5. Time release;
6. Check locking;
7. Automatic train stops.

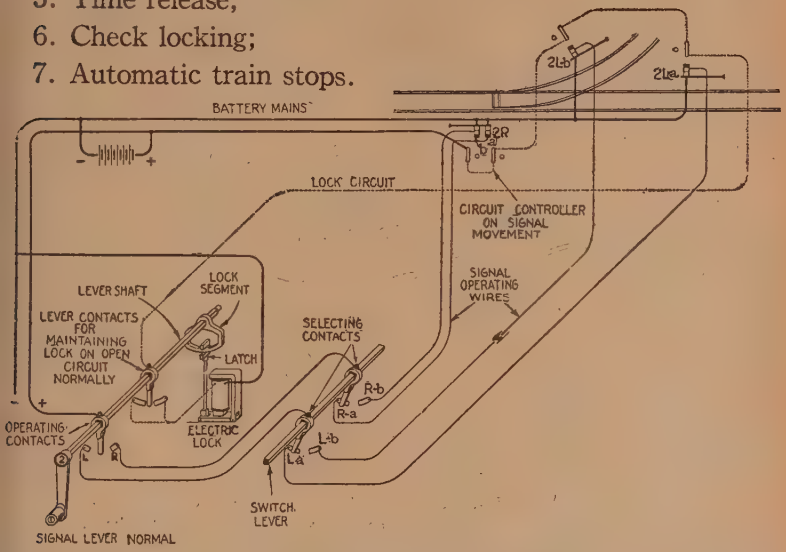


FIG. 6,675.—Diagram of complete ***signal control*** and indication circuits; ***lever and signals normal.***

Numerous accompanying diagrams are given to illustrate the auxiliary features.

Signal Lever Operation and Control.—The signal levers of the electro-pneumatic machines occupy five distinct positions as shown in fig. 6,626, when used to *full capacity*.*

*NOTE.—***Full capacity*** means the use of the lever to the right for the operation of one signal or set of signals and to the left for another signal or set of signals, the two sets necessarily conflicting, always, with each other in respect to the route or routes governed by them. This feature gives to each signal lever the capacity of two levers.

Evidently from figs. 6,675 to 6,680 the signal levers normally occupy a vertical central position; when moved to the extreme right, a signal is operated that governs traffic over a given track in one direction; when thrown to the left, a signal is operated which governs traffic over the same track in an opposite direction, or in any direction over any conflicting track, as convenience of manipulation may determine in arranging lever functions. Any signal thus operated to proceed, applies an electric lock to the signal lever and prevents the full return of the lever to the normal until

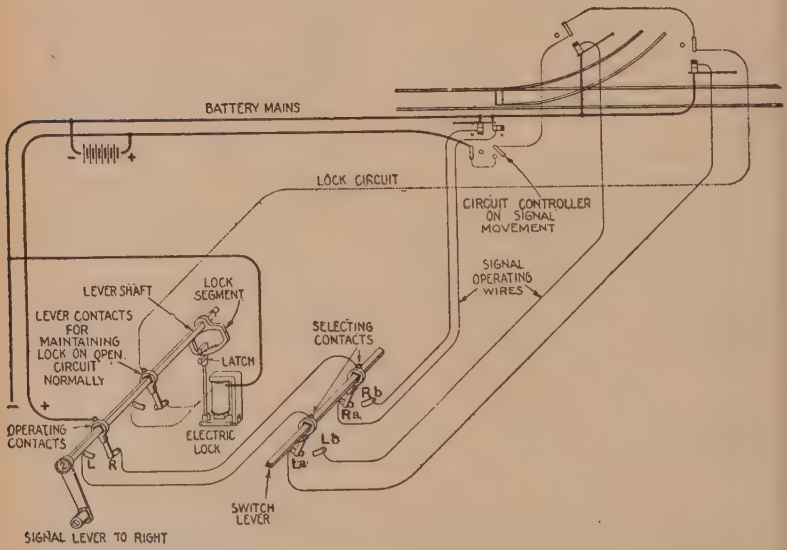
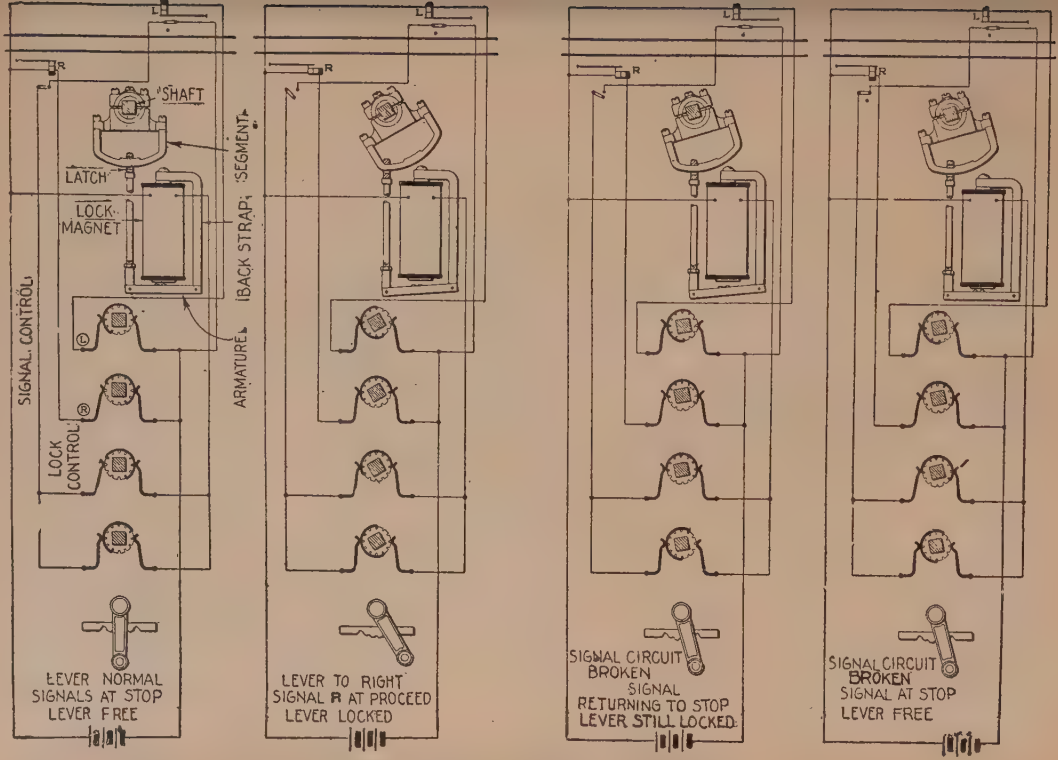


FIG. 6,676.—Diagram of complete ***signal control*** and indication circuits; ***lever and one signal reversed.***

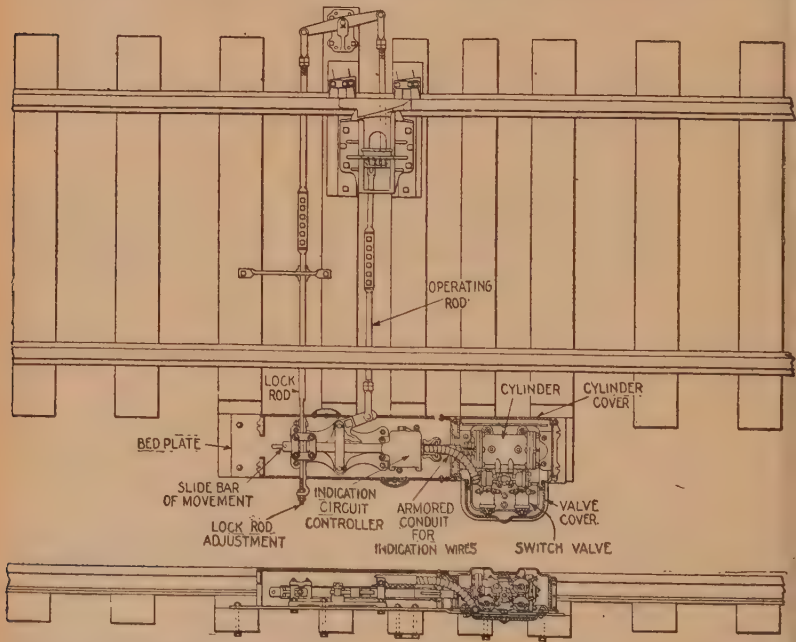
the signal, in response to a partial return of the lever toward normal, re-energizes the lock and releases the lever for this final movement.

Positions D, and B, of the diagram, fig. 6,626, represent those assumed by signal levers when moved from their extreme positions, represented by lines L, and R, to restore signals to the stop position and beyond which they cannot be moved, toward their central normal position, until the signal assumes the stop position.



FIGS. 6,677 to 6,680.—Diagram of signal lever and circuits for selecting opposing signals.

Switch Operation and Control.—Switches are unlocked, operated and again locked by one continuous operation of the prime mover, the cylinder. Its characteristics are shown in figs. 6,681 to 6,686. As before stated, switch and lock move-



FIGS. 6,681 and 6,682.—Union S. and S. Co. electro-pneumatic switch and lock movement applied to a Hayes derail. The switch and lock movements comprise a slide bar moved in a longitudinal direction by the cylinder to unlock, operate and again to lock the switch through the medium of an alligator jaw crank engaging it.

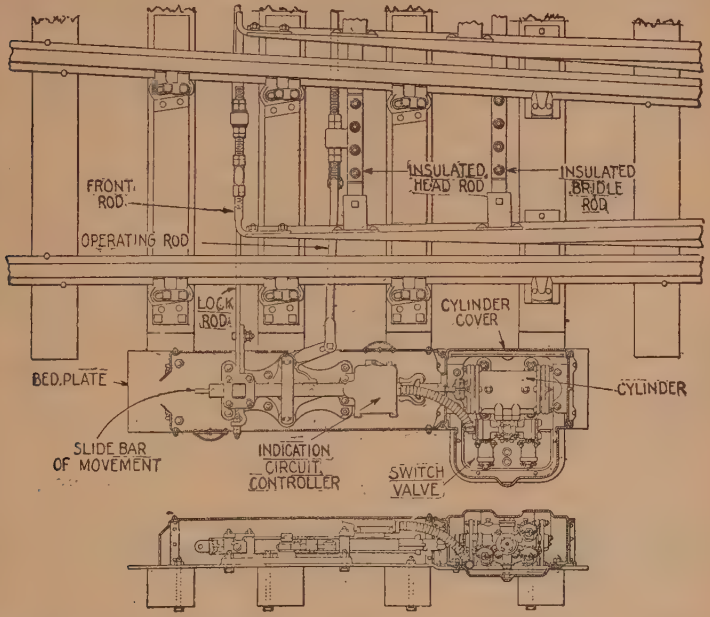
ments are applied to the operation of switches of every character and rail section.

The equipment as shown in figs. 6,681 to 6,684 consists of four separate elements:

1. Switch valve;

2. Switch cylinder;
3. Switch and lock movement;
4. Indication circuit controller.

These details are shown in the accompanying illustrations.

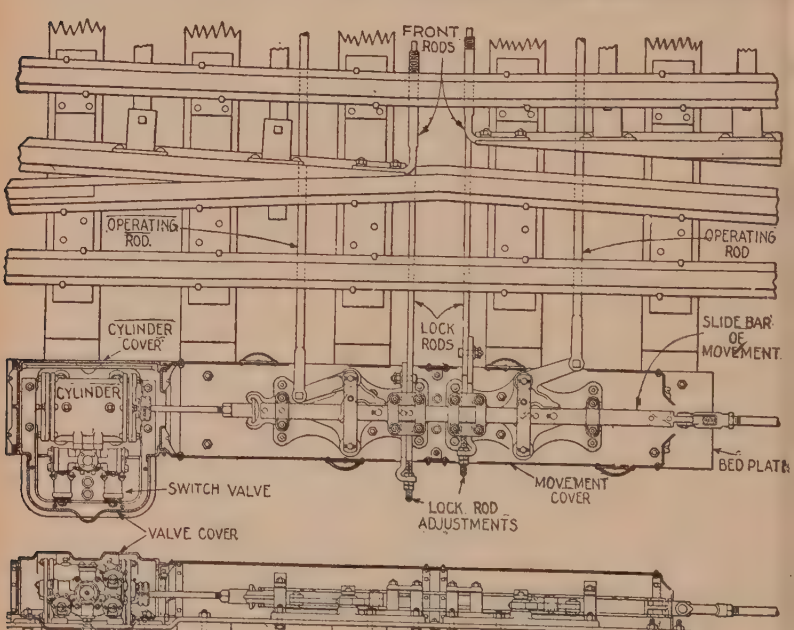


FIGS. 6,683 and 6,684.—Union S. and S. Co. electro-pneumatic switch and lock movement applied to one end of a double slip switch.

Signal Operation and Control.—Figs. 6,687 and 6,688 show the *signal motor* of the system comprising the magnet and pin valve already described, the cylinder and the piston by which the signal is operated from one of its positions to another.

Where a signal embraces three positions of indication, two such devices are employed to act jointly upon it, one for each proceed indication displayed.

Attached to the signal motor is a circuit controller that actuates certain electric contacts at predetermined positions of the signal. These contacts control the electric locks of signal levers whereby the latter may not be restored to normal until the signals which they operate have first assumed the stop position; they also control the circuits of other signals and govern



FIGS. 6,685 and 6,686.—Union S. and S. Co. electro-pneumatic switch and lock movement applied to a movable point frog.

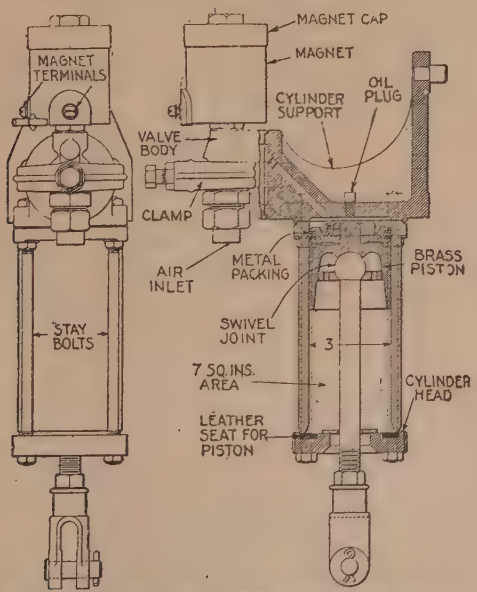
the display, by the other signals, of those indications which relate to conditions more or less common to both.

Approach, Detector and Sectional Route Locking.—That feature of automatic lever locking by trains, which is peculiar to the action of trains prior to their entrance upon the switches of

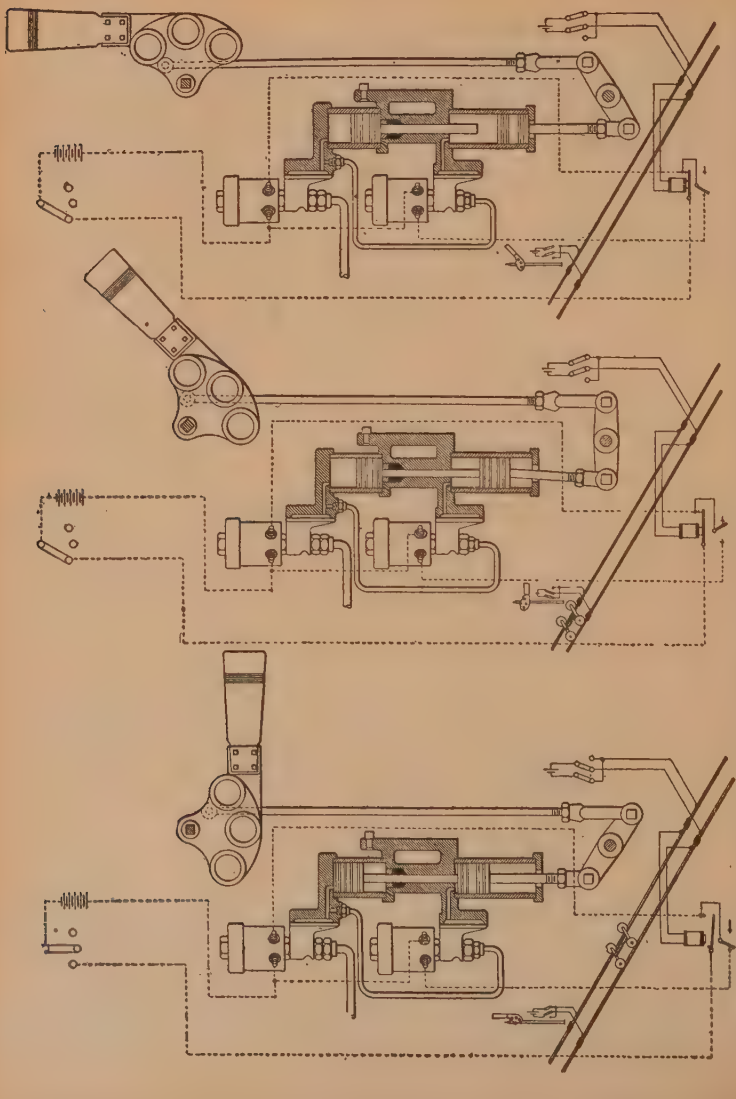
the interlocking, is generally referred to as *approach locking*, and embraces also *the automatic announcement of trains*.

That feature which involves the action of lever locks by train movement over the switches of the interlocking, is generally termed detector locking and sectional route locking. The latter feature embraces, besides the automatic locking and releasing of switch levers, the semi-automatic control of signals by trains through the medium of track circuits common to both.

Calling on Arms.—In the diagram, fig. 6,692, for simplicity, only the circuits peculiar to the operation and control of the



FIGS. 6,687 and 6,688.—Union S. and S. Co. signal motor. In three position signals, while a single cylinder, valve and magnet are employed for each of the two proceed indications displayed by such signals, the air supply is direct from the main to that valve and cylinder only by which the caution or 45° position is displayed; the air supply to the other valve and cylinder being drawn from the 45° position cylinder. This is done to insure that the 90 position of the signal is always dependent upon the complete prior activity of the 45° mechanism, and that the interruption of either the air pressure or the electrical current by which the signal is held in the vertical position will insure its return therefrom whichever magnet or valve may be deprived of power.



FIGS. 6,689 to 6,691.—Diagrams of three position, upper quadrant, semi-automatic, electro-pneumatic signals, showing joint operation from the interlocking machine and by automatic train action upon the track it governs.

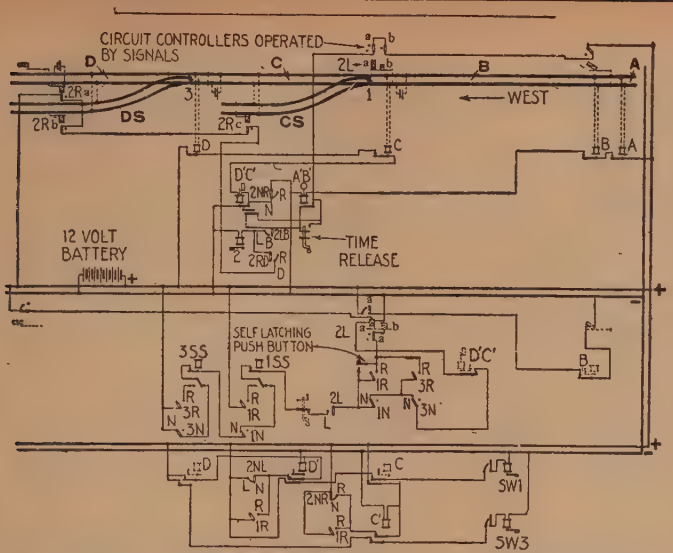


FIG. 6,692.—Diagram of sectional route locking circuits. It will be noted that the rails of each switch are included within separate track circuits, and that these circuits embrace both leads as far as their fouling points, and extend in each direction to the signals governing movements over these two switches. A track circuit also extends from the signal which primarily governs the first switch to the preceding signal, usually called the distant signal. A fourth section also extends from this distant signal to a point preceding it 3,000 ft. or more. These sections are designated D, C, B, and A, the switches, 1 and 3, corresponding with the numbers of the two levers assigned to their operation. The signals are all operated by lever No. 2; the three east bound signals being operated by the lever thrown to the right and the two arms of the west bound signal by the lever thrown to the left, this being possible because each of these signals conflicts with each other signal under all circumstances. The operation of signal 2L-a, for a west bound train requires that switches 1 and 3, be set and locked as shown, before lever 2, may be moved to operate the signal. The operation of lever 2, to the left through the mechanical locking of the machine locks levers 1 and 3, normal, and hence the switches 1 and 3, for the route governed by the signal so long as lever 2, remains moved from its normal position. ***Approach locking.*** Even though signal 2L-a, be restored to the stop position by the partial return of the signal lever toward normal, the switches of the route still remain mechanically locked. It is evident too, that whether lever 2, is retained out of its normal (central) position by choice or by compulsion, the switches remain locked with equal security. The return of signal 2L-a, to normal, ordinarily, releases the lever for its restoration to normal; where route locking is in vogue, this release of the lever by the signal's return is made dependent upon an added condition.*

*NOTE.—***This condition*** is that a train has not, previous to the signal's return, entered upon the track circuits A or B. If the train has so entered, its approach is automatically announced to the operator by annunciator A'B', and the electric lock of lever 2, is retained upon open circuit during the train's presence, upon either of the sections. Before the annunciator A'B', can be re-energized to release the lock 2, the train must have left sections A and B completely. If its leaving was by permission of signal 2L, the train naturally entered

NOTE.—*Continued.*

upon section C, before it left section B. This act causes, through relay C, the indicator D'C' to become de-energized before the annunciator A'B' becomes re-energized and releases the lock of lever 2, whereby that lever becomes free to be put normal and the mechanical release of switches 1, and 3, becomes possible. The release of lever 2, by indicator D'C' when this indicator is de-energized has another important function.

NOTE.—***If a second train*** (in fig. 6,692) enter section A B, before lever 2, is restored, this lever having been thrown to clear signal 2L, for a previous train, indicator D'C', will not pick up, being a stick indicator. The release circuit, through a back contact of indicator D'C', will remain closed and allow the leverman to restore lever 2, although the lock circuit of lever 2, is open through indicator A'B' The signal lever may also be restored while a train is in section A B, by the use of a time release, the operation of which is described in a subsequent paragraph. Should lever 2, be restored to normal after a train has accepted signal 2L, the release, mechanically, of levers 1, and 3, that follows is without danger, because the entrance of the train upon section C, that necessarily preceded this event, caused, through relay C, the interruption of the electric lock circuit of lever 1, and through stick relay C', the interruption of the electric lock circuit of lever 3; thus effectually retaining these levers still locked against operation, but by direct electric means peculiar to each.

NOTE.—***Switch locking.*** While switch levers are locked automatically in groups by train action upon the first switch of the group, their release must occur not in like manner by the exit of the train from the last switch of the group, but each lever must be released individually as the train passes over its switch and clear of the fouling limits of the switch leads. The movement of the train westward off of section C, and into section D, causes relay C, and stick relay C' to become re-energized and the electric lock of lever 1, released. Before this occurs, however, relay D, has been de-energized, by the entrance of the train upon section D, in its movement from section C, and hence the circuit of lock 3, is continued open at relay D, notwithstanding its closure at relay C', and lever 3, still remains locked until the train passes entirely clear of section D, and until relay D, becomes thereby re-energized. It will be observed that stick relay D', is not operated with relay D, for were this done, the lock circuit of lever 1, would be opened thereby and the release of switch 1, which is desirable, would not follow the train's exit from section C. The action of the train on section D, and the consequent de-energization of relay D, would not open the circuit of relay D', because of a by pass formed by lever 2, when that lever is not in a position for governing east bound traffic. This by pass bridges the open contact of relay D, and prevents the action of relay D, for west bound traffic; when lever 2, is thrown to the right, however, for signaling east bound traffic, the train's action upon section D, operates not only relay D, but also the relay D', thereby opening the lock circuits of both levers 1 and 3. Upon passing on to section C, relay C, only is de-energized and not relay C', as when the west bound train entered section C, from section B. Relay C' is thus retained in an energized state by virtue of a by pass formed by lever 2, when that lever is in any position other than that employed for east bound traffic, and hence when the train moves from section D, into section C, the re-energization of relay D, closes the lock circuit of lever 3, and releases switch 3, for possible operation. This would not occur did not the relay C', remain energized, through the by pass referred to. The lock circuit of lever 1, is necessarily opened by relay C, before the exit of the train from section D, into section C, fully occurs, so that after the occurrence, when both relay D, and relay D', are energized, the circuit of lock 1, remains open at relay C, and until the train passes clear of section C, whereupon switch 1, may be moved if desired. It will also be observed that when switch 1, is reversed, a by pass is established on stick relay D', which causes this relay to remain energized regardless of the condition of track relay D. The purpose of this by pass is as follows: With switch 1, reversed and a west bound train having not yet cleared section D, if signal 2R-c, were cleared for a second train to move from siding CS, to the main line, stick relay D', would open if it were not for this by pass and switch 1, would be locked and remain locked as long as the first train stood on section D, thus preventing all movements of traffic over switch 1, in its normal position. A similar by pass acts on stick relay C', and prevents switch 3, from being locked while a train is passing into siding CS, after having accepted signal 2L-b.

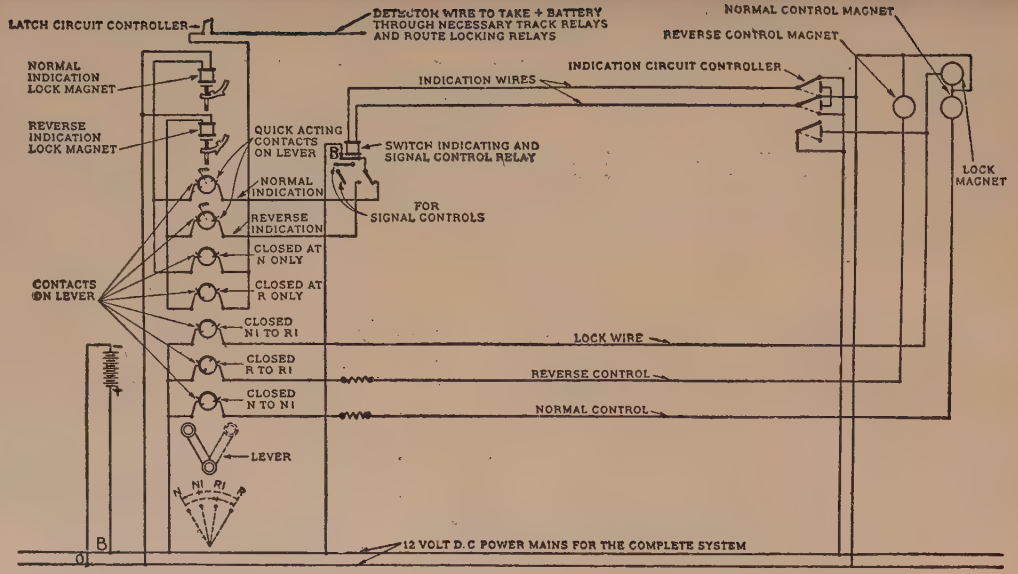


FIG. 6,693.—Diagram of complete control, indication and locking circuits for single switch with *d.c.* indication.

two westbound signal arms are shown. The top arm only is under automatic control by trains, through the indicator D′, C′, the lower or "calling on" arm being assigned to movements into either one of the two sidings whether these be occupied or not, and also to the main track D, only in case that track is already occupied, and the top arm is hence restrained against operation by indicator D′, C′, for such train movements.

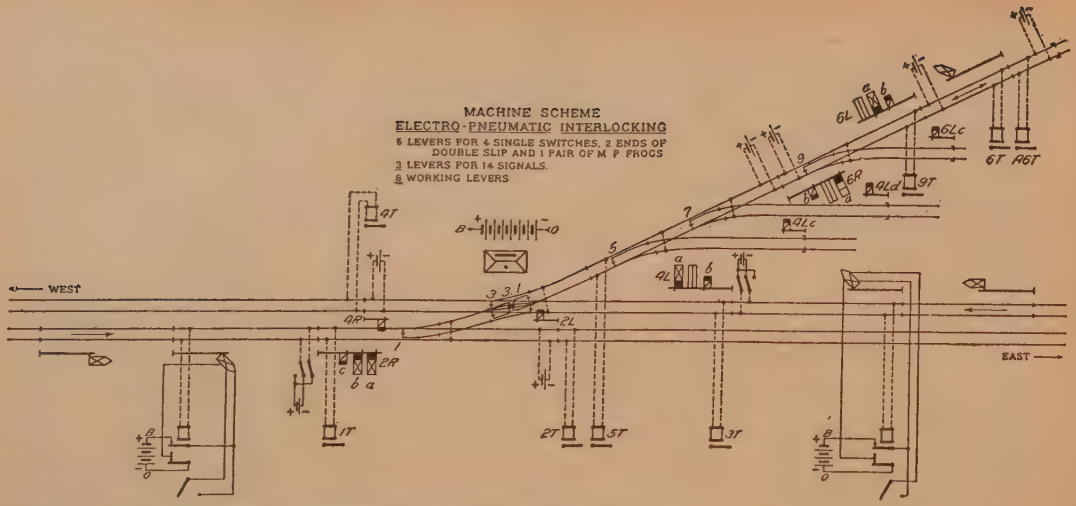


FIG. 6,694.—Complete layout of small electro-pneumatic interlocking plant.

NOTE.—***Clockwork time release.*** The operation of the time release is to unlock electrically during emergencies a lever properly held locked by train action, and requires first, a distinct action by the leverman, and second, that a sufficient period of time must elapse, following this action, to insure that the train, which is locking this lever, has either stopped or is traveling at a reduced speed, before the lever is restored to its normal position. It is also to compel the restoration of the time release to its normal position after each operation, before signals can be again operated for traffic movement under them, that signal circuits are thus controlled by contacts on the time release.*

*NOTE.—***The current supply** to both signals is further drawn through contacts of other devices than the indicator D'C' (fig. 6,692) and the time release. In order to insure that a misplaced switch, wrongfully set from any cause out of coincidence with the new position of its operating lever, and to insure also that a lever which from any cause assumes a position at variance with that of the switch it operated, may effectually prevent the display at such times of any signal giving proceed rights over the switch, this current supply is also drawn through the contacts of the switch indicating relay and through corresponding contacts operated by the switch levers.

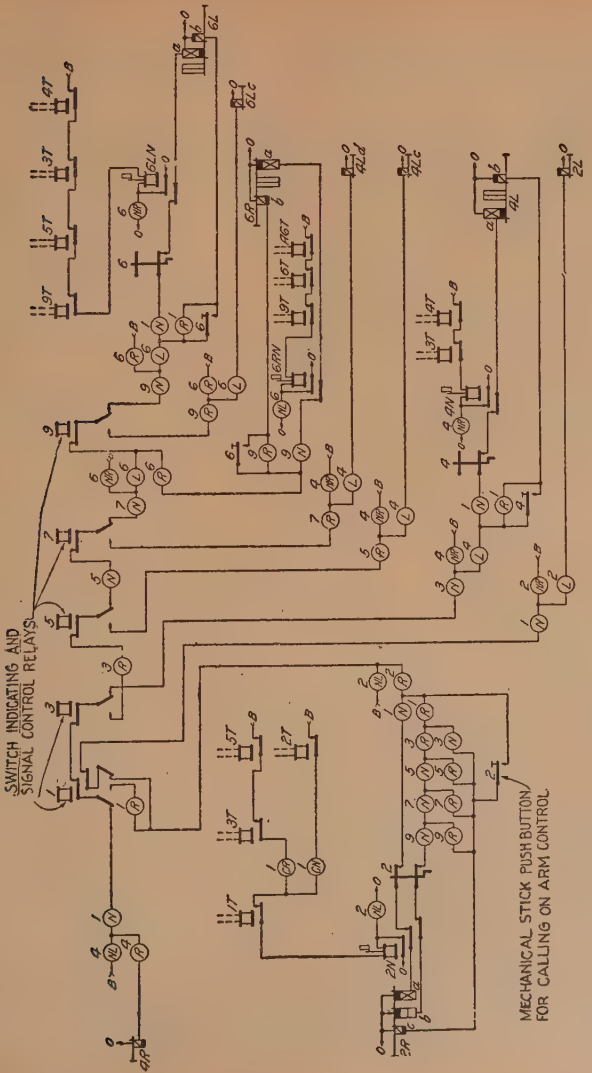


FIG 6,695.—Signal control circuits for plant shown in fig. 6,694.

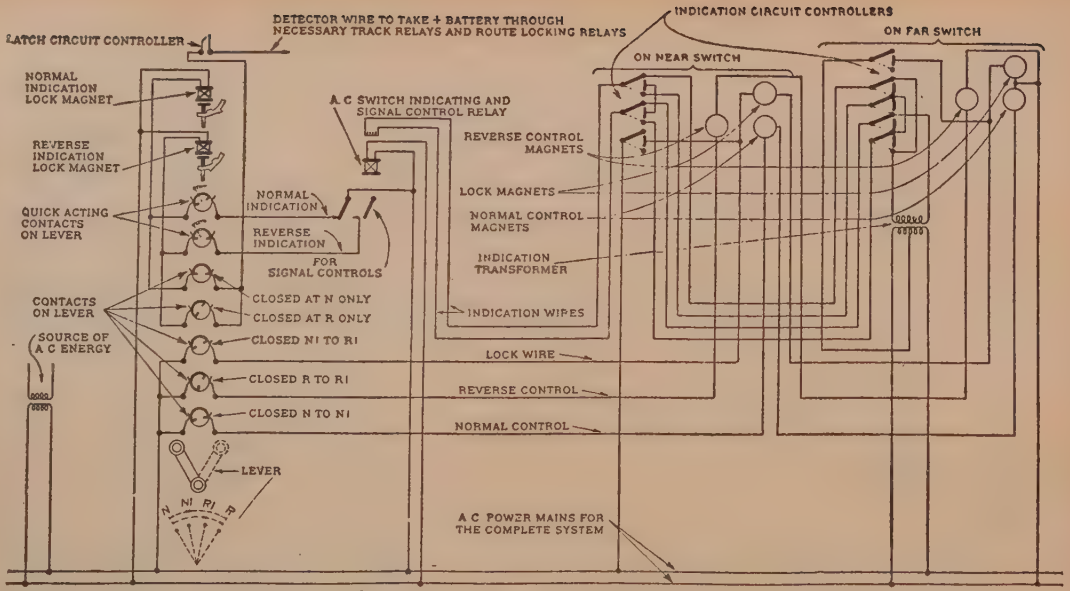


FIG. 6,696.—Diagram of complete control, indication and locking circuits for crossover with *a.c.* indication.

The use of the lower arm in this capacity is, as shown, not possible by lever action alone, but demands in addition the operation of a push button which is mounted behind the signal levers so that its operation is convenient only when the lever is moved from normal, a movement that must necessarily precede the effective use of the button for clearing the calling on arm. This button, when depressed, closes a pair of contacts in the signal circuits that are effective to clear the calling on arm providing the high speed signal above it is in the stop position, and providing also that the signal lever 2, is moved to the left.

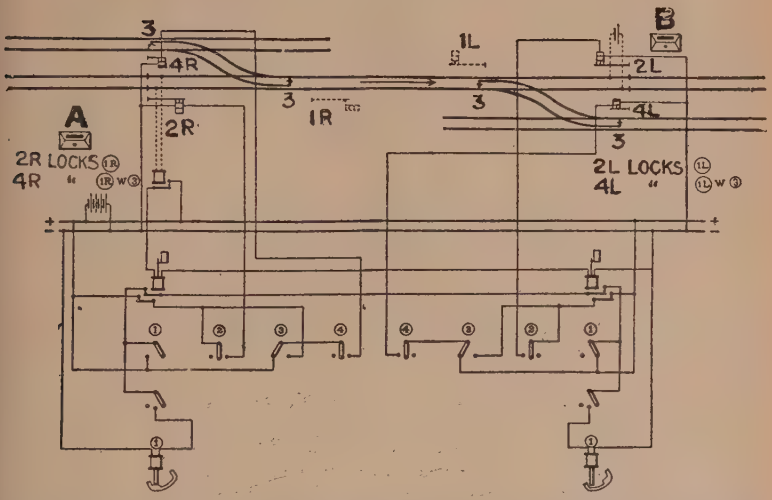


FIG. 6,697.—Check locking or locking between towers. ***In the diagram*** lever 1L, of tower B, and lever 1R, of tower A, are the master levers while 2L, and 4L, are the actual signal levers of tower B; and 2R, and 4R, are those of tower A. Assuming a gauntlet track being unoccupied, and each towerman being made aware of this by his indicator, A, may desire to move a train under signal 2R, to B. This he can do under the conditions prevailing, because signal lever 2R, is free to be moved when master lever 1R, is thrown to the right as shown. This action of lever 2R, however, operates the signal only upon condition that the current supply to the signal is not interrupted by either or both of the tower indicators. A train acting upon the authority of signal 2R, operates that signal automatically to stop through the medium of the track circuit and the tower indicators controlled therefrom, and simultaneously retains the locks of levers 1R, and 1L, upon open circuit until it passes completely from the track circuit. While levers 1R, and 1L, may at any time be placed in their central position, that one at A, lever 1R, may be moved only to the extreme left at all times while that one at B, lever 1L, may be moved only to the extreme right at all times. The application of the electric locks to these levers by train action restrains but one of the master levers against full reversal. For the direction of traffic shown in the diagram, lever 1L, tower B, is so restrained, while for traffic in the opposite direction lever 1R, tower A, is likewise restrained. When the train has passed clear of the gauntlet track section both indicators give evidence of the fact and the master levers may then be operated to change the direction of traffic. Reversal of 1R, locks mechanically signals 2R, and 4R, against operation while reversal of 1L, releases signals 2L, and 4L, for operation. A west bound train now acting upon authority of signal 2L, or 4L, de-energizes both indicators and retains both electric locks upon open circuit as before. Now, however, it is lever 1R, that is restricted against full operation in reverse by the train until the latter has passed clear of the gauntlet section, thus automatically holding traffic over the gauntlet to conform with its own direction.

The current supply to both arms is also drawn through contacts of a device known as a time release, as shown in fig. 6,692, and already referred to in a general way. This is done in order to insure that the first act of its operation will be to open the signal circuit and thus prevent any possible operation of the signals until the device has been again returned to its original position.

Check Locking or Locking Between Towers.—The first requisite of a safe method to prevent the simultaneous entrance of trains from opposite directions onto a piece of common track is *the interlocking of the two signal levers by which movements to such a track are governed.* This is also known as "*traffic locking.*"

When both levers are comprised in a single machine, both signals embraced in the same interlocking, this interlocking is done mechanically and in a very simple way well understood. When, however, the levers constitute elements of two separate machines, the signals embraced in two different interlockings, the locking is not practicable by purely mechanical means and is accomplished electrically. Usually, more than one signal governs train movements for each interlocking over a gauntlet track. To obtain the simplest circuits and the least number of instruments, contacts, etc., for the protection sought in such cases, an independent lever in each interlocking is employed as a *master* lever and it is to these levers that the electric locking is applied; these levers, through the mechanical locking of the machine, being locked by each signal lever of the machine giving train rights over the gauntlet track.

TEST QUESTIONS

1. *What is an electro-pneumatic system?*
2. *What is the advantage of the electro-pneumatic system?*
3. *Of what does the system consist?*
4. *How is the compressed air obtained?*
5. *Is the source of electricity for the control of the various appliances usually already available?*
6. *Describe at great length the electro-pneumatic interlocking machine.*
7. *Explain switch operation and control.*
8. *How is the operation of the slide valve effected?*
9. *Name the different safety devices employed.*
10. *What are detector bars?*
11. *Describe the indication circuit control.*
12. *Draw a diagram of complete switch control.*
13. *How are the indication magnets controlled by the quick switch?*
14. *How is each signal of the system operated?*
15. *Name the special auxiliary features.*
16. *Describe the signal lever operation and control.*
17. *Describe the switch operation and control.*
18. *Explain approach, detector and sectional route locking.*
19. *Define the term "calling on arms."*

20. *How is the top arm controlled?*
21. *What is the other name given to check locking?*
22. *Explain check locking.*
23. *What is a gauntlet track?*

CHAPTER 150

Automatic Train Control

The object of this system is *to enforce the observance of the speed restricting indications of wayside signals by compelling the engineman to perform some manual act called* ***acknowledging*** *when passing such signals.* By speed restricting indications is meant both the caution and stop indications of wayside signals.

Penalty for Failure to Acknowledge Restrictive Signals.—The penalty for failure to acknowledge either a caution or stop signal is an automatic brake application from which the brakes cannot be released until the train has been brought to a stop.

Transmission of Control Wayside to Locomotive.—The control device between the wayside and the locomotive is composed of two parts:

1. Receiver;
2. Inductor.

The receiver is securely fastened to the trucks of the locomotive; the inductor to special ties with its pole face 2½ ins. above the top of the running rail and its center line parallel with and usually 19½ ins. outside the gauge line.

The receiver is adjusted so that as the locomotive moves along the track the pole faces of the receiver pass about 2 ins. above and directly over the inductor pole faces. Fig. 6,698 shows the essentials of receiver and inductor.

In action when the receiver carried by a locomotive approaches an unwound inductor or a wound inductor on open

circuit, *a surge of magnetic flux builds up in the secondary coi and produces a negative current in the relay* as shown by curv ABC, fig. 6,699.

This negative current is sufficient to allow the relay to open, and onc open stays open until restored due to its being a stick relay.

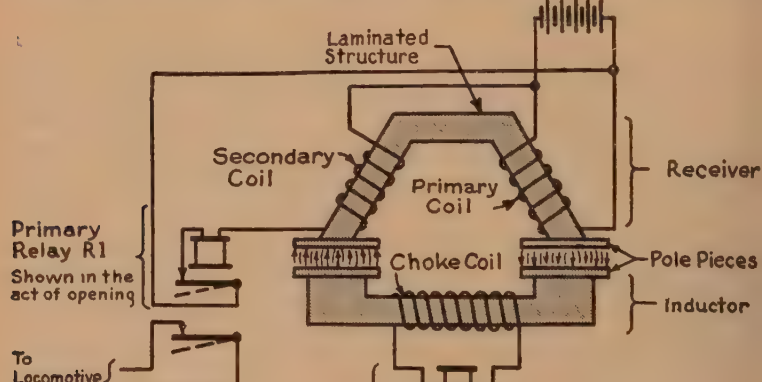


FIG. 6,698.—Diagram of *receiver* and *inductor* illustrating construction and principles c control wayside to locomotive. The receiver consists of an inverted U shaped magnet wit laminated cores, large pole pieces and two coils. The inductor consists of a U shaped magne with laminated cores and large pole pieces the same shape, size and spacing as the pole piece of the receiver. One of the two coils of the receiver is called the primary coil, and being cor stantly energized from a source of electrical energy, it produces a strong magnetic field. Th other coil, called the secondary coil, is connected to the same source of energy and in serie with the coil and front contact of relay R1, through which a current of about 14 milli-amperc flows normally Certain of the inductors which are used in this combination are calle wound inductors. Thes.. are provided with a choke coil which is automatically controlled i such a way that when a speed restricting impulse is to be given the coil is an open circuit an when no impulse is to be given the coil is closed on itself. Other inductors have no choke coi and they will therefore always act to give a speed restricting impulse. They are calle unwound inductors.

Current curve ABCDE, shows approximately how the normal batter current through the relay R1, would be varied as the result of a receive passing an inductor on open circuit if said relay were non-stick, the ampl tude of the cycle varying with the speed at which the receiver passes th inductor.

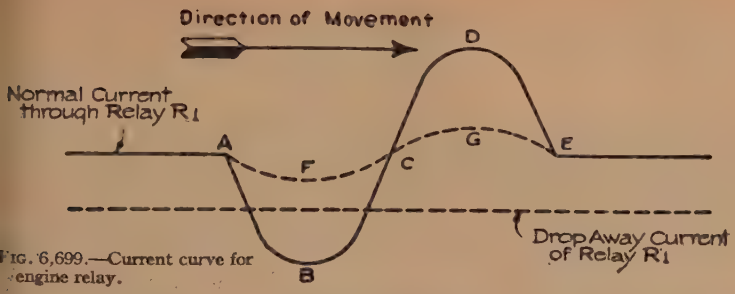


FIG. 6,699.—Current curve for engine relay.

FIG. 6,700.—General Railway Signal Co. receiver and inductor mountings, receiver mounted to truck side frame. The receiver proper is protected by a non-magnetic casing which is adjustably mounted to one of the tender trucks in such a way that no car springs intervene between the receiver and the car axle. The terminals for the receiver windings are made accessible for testing and inspecting by removing a small cover plate on the side of the receiver housing. The wires leading from the receiver are connected to the locomotive wiring through a plug coupling which facilitates the making of repairs to locomotives as well as the manner of replacing the receiver.

Incidentally, it is to be noted that this is a valuable characteristic of purely inductive device such as this, namely, that the power of the transmitted electrical impulse increases with speed.

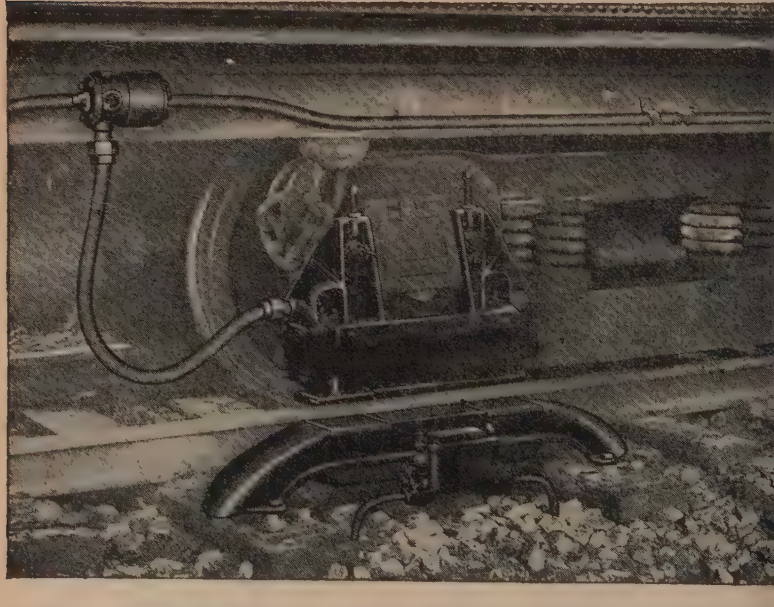


FIG. 6,701.—General Railway Signal Co. receiver and inductor mountings, receiver mounted on journal box. The inductor is protected by a strong, ramp shaped, non-magnetic housing securely fastened, through special ties, to the rails in such a manner as to maintain correct operative relation between the rail and the inductor. The two terminals for the inductor winding are located in an outlet box attached to the under part of the inductor housing, and the connecting wires lead into trunking through flexible conduit or into parkway cable.

Current curve AFCGE, shows approximately how the normal battery current through relay R1, would vary as the result of a receiver passing an inductor on closed circuit, which would be the case under clear conditions. The amplitude of the cycle AFCGE, as a result of the effect of the choke coil, is never enough to cause relay R1, to open.

Figs. 6,700 and 6,701 show the manner in which inductors and receivers are protected and the most approved means of mounting.

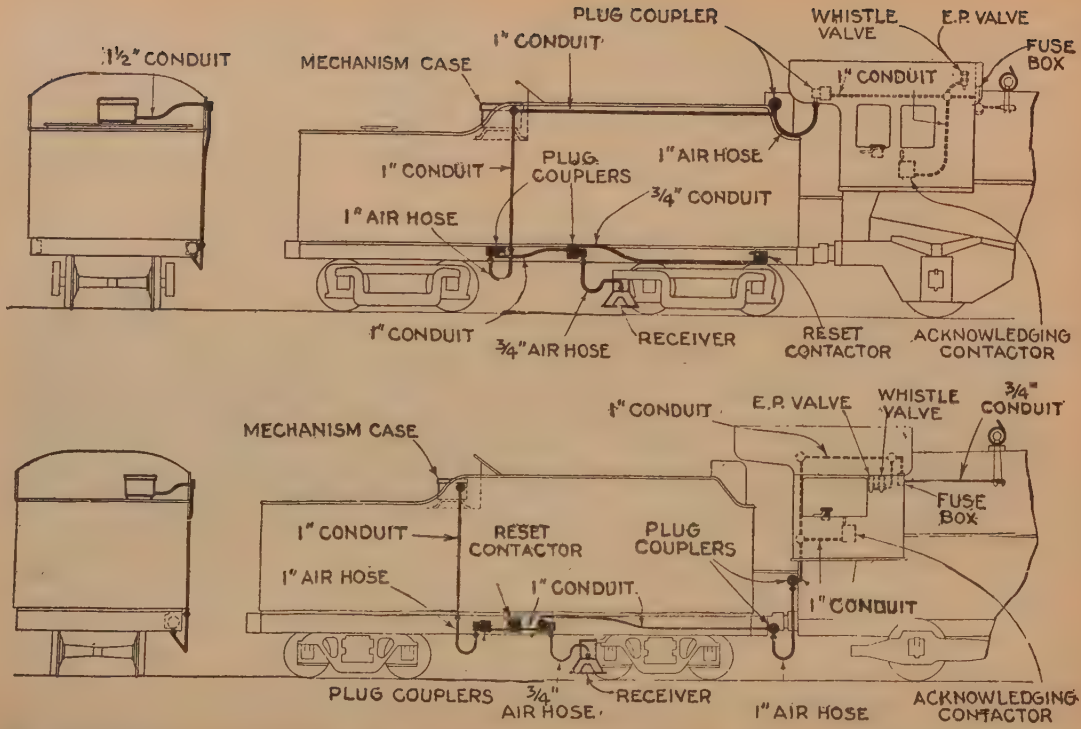
FIG. 6,702.—Southern Railway locomotive showing location of automatic train control apparatus.

Brake Applying Apparatus.—The devices employed in applying the brake consist of:

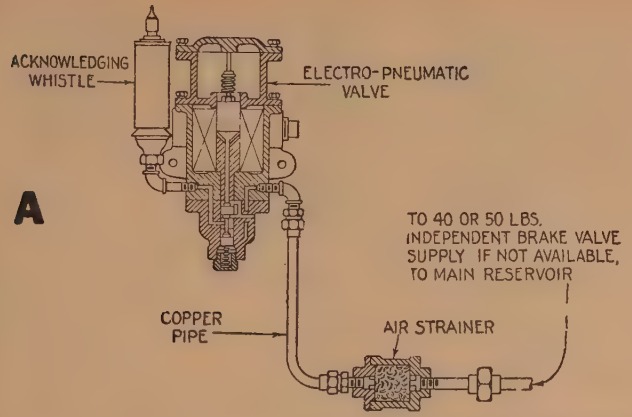
1. Electro-pneumatic valve;
2. Brake valve actuator.

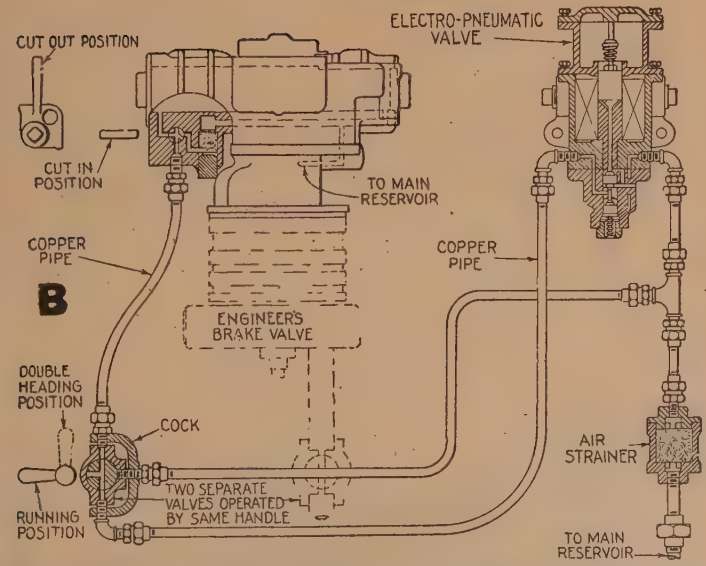
Ques. What is the actuator?

Ans. An air operated differential piston and mechanism mounted on the automatic brake valve.

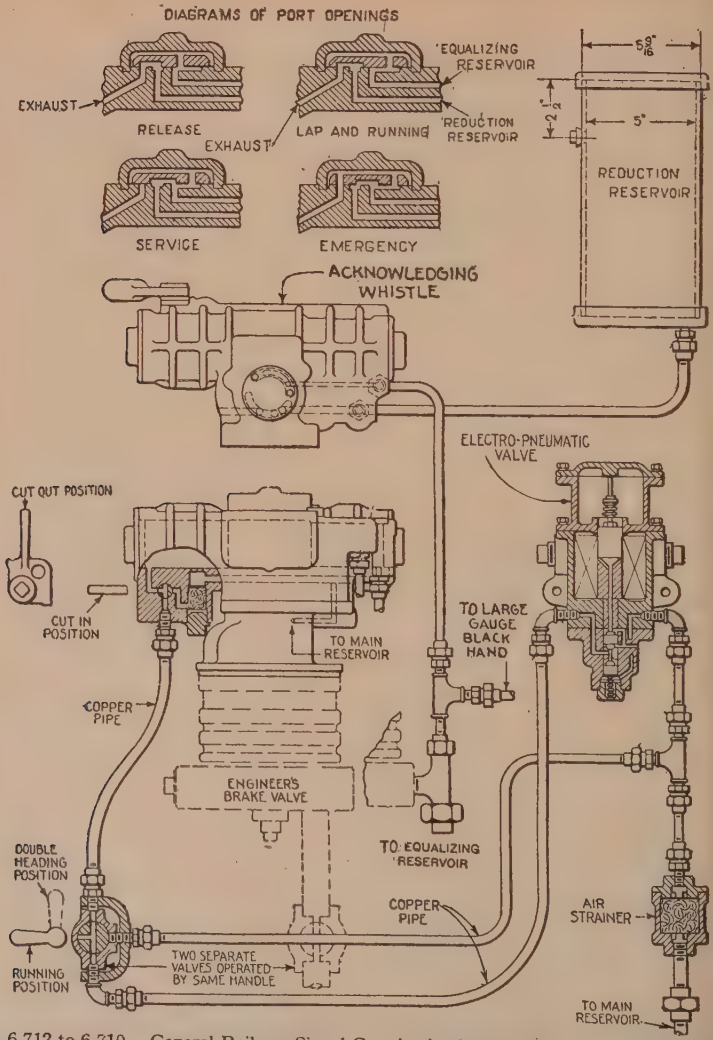


FIGS. 6,703 to 6,706.—General Railway Signal Co. automatic train control apparatus. Diagram showing location of parts and





FIGS. 6,707 to 6,711.—General Railway Signal Co. air pipe layout for actuator giving unlimited brake pipe reduction. **A**, air pipe layout for acknowledging whistle; **B**, air pipe layout for actuator.



FIGS. 6,712 to 6,719.—General Railway Signal Co. air pipe layout for actuator giving limite brake pipe reduction.

Ques. What is the purpose of the actuator?

Ans. To move the rotary valve to the service position automatically when air is exhausted from behind the large piston.

The actuator is designed to be used with or without a means for limiting the service application to a pre-determined brake pipe pressure reduction.

Ques. What is the acknowledger?

Ans. An electrical contactor operated by a lever.

Ques. What is the purpose of the acknowledger?

Ans. It is used to prevent an automatic application of the brakes when passing a caution or a stop signal.

If the lever of an acknowledger be held down for a longer period than 15 seconds, an automatic brake application will result.

Ques. What is the purpose of the reset contactor?

Ans. It is used after an automatic application of the brakes to restore the electrical apparatus.

The push button is pressed for two seconds and then released after which the brake applying apparatus may be restored to normal.

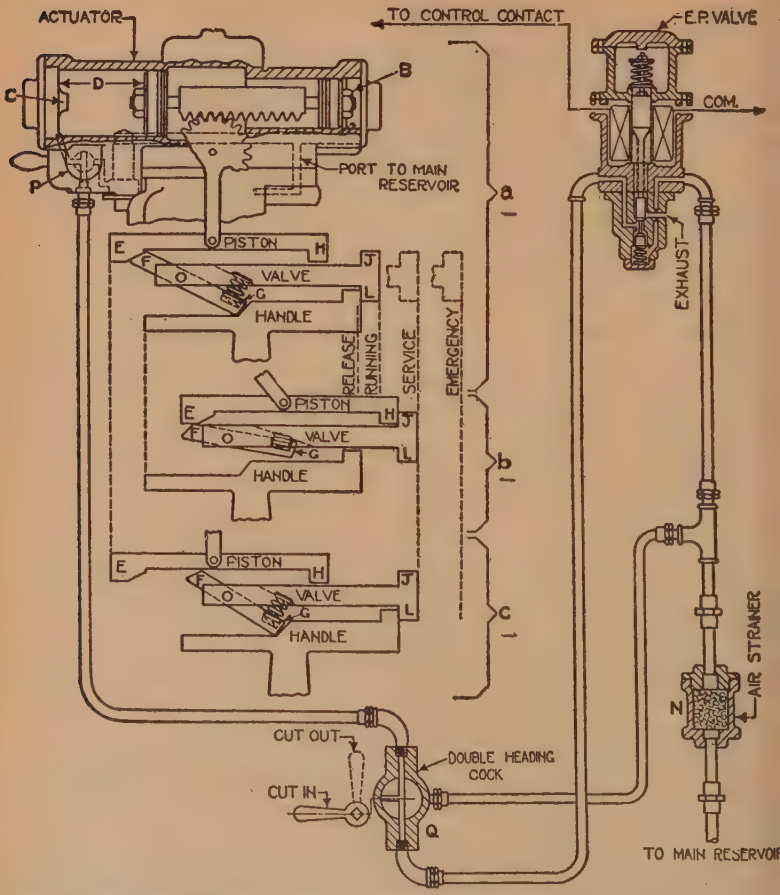
Ques. What is the electro-pneumatic valve?

Ans. An electrically operated air valve used to control the operation of the actuator.

In operation, when energized it connects main reservoir to the large cylinder, left hand side, of actuator, and when de-energized, it blanks main reservoir and vents the large cylinder of actuator to atmosphere.

Ques. What is the whistle valve?

Ans. An electrically operated air valve used to sound an acknowledging whistle.



FIGS. 6,720 and 6,721.—Diagram showing principles of brake applying apparatus. ***In operation.*** Under all conditions, air direct from the main reservoir is supplied to the cylinder B, which is the smaller of the two cylinders of the actuator. When the E.P. valve is energized, air is supplied from the same source through the air strainer N, the E.P. valve, the double heading cock Q, and the cut out cock P, to cylinder D, the larger of the two cylinders of the actuator. The part marked *piston* is, therefore, shifted to the extreme left hand position as indicated in that part of the diagram shown within the bracket, a. Under these conditions the actuator is entirely disconnected from the brake valve handle so that the engineer has the same control of the brake valve that he would have if the actuator did not exist. When the E.P. valve is

It is energized momentarily when a caution or stop signal is acknowledged and during this short interval connects the independent brake valve air supply or main reservoir to the acknowledging whistle.

The diagram fig. 6,720, shows the operation of the actuator. In the diagram, the part marked *piston* is attached to and operated by the piston of the actuating cylinder. The part marked *valve* is connected to the *rotary* of the brake valve. The part marked *handle* is connected to and moves with the brake valve handle.

In the explanation of fig. 6,720 it is assumed that the reader is familiar with the regular air braking equipment used on locomotives.

Where it is desired to limit the service application to a predetermined reduction in brake pipe pressure, the equalizing reservoir is connected to a reduction reservoir of the proper capacity, through an additional rotary valve which is connected to the regular valve, the part marked *valve* in diagram, fig. 6,720.

When the regular valve is in any position between release and lap, this additional rotary valve opens the reduction reservoir to atmosphere and closes the connection from the equalizing reservoir to the reduction reservoir.

FIGS. 6,720 and 6,721.—*Text continued.*

de-energized, air is exhausted from the cylinder D, which allows air in the cylinder B, to move the actuator piston to the left until it comes against stop C. During the first part of this movement, the cam surface E, on the part marked *piston*, being moved to the right, comes in contact with the latch FG, which is attached to the valve, lifting the portion G, out of engagement with the handle. During the rest of the movement, the lug H, on the piston is in contact with the projection J, on the valve so that the valve is moved to the right to the service position as indicated in that part of the diagram included within the bracket, b. In this position, it will be noted that the *handle* is disconnected from the valve in such manner that the valve cannot be moved by the handle toward the left or release position. The valve can, however, be moved to the right or emergency position. The engineer can, therefore, at any time, make an emergency application, but he cannot again move the brake valve until the E.P. valve is re-energized by a reset which cannot be done until the train has been brought to a stop, as will be explained later. In order to regain control of the brake valve after it has been moved to the service position by the actuator as explained above, the E.P. valve must first be re-energized by the operation of a reset contactor. This allows air to again flow into cylinder D, of the actuator which moves the part marked *piston* back to its original position, as shown in that part of the diagram included within the bracket, c. The engineer then places the brake valve handle in the service position which permits latch FG, of the valve to engage the handle, after which he has regained control of the valve and may release. It is therefore noted that the service application put on by the actuator is entirely automatic, whereas, the release from this application is a manual operation.

When the regular valve is moved to the service position, either manually or by the actuator, the additional valve closes the reduction reservoir to atmosphere and opens the connection to the equalizing reservoir, allowing air to discharge through a limited orifice of the proper size from the equalizing reservoir into the reduction reservoir. Therefore, after the pressure in the two reservoirs equalizes, the reduction in brake pipe pressure will stop when it reaches a pressure equal to that in the reservoirs. This limits the reduction to an amount determined by the capacity of the reduction reservoir used.

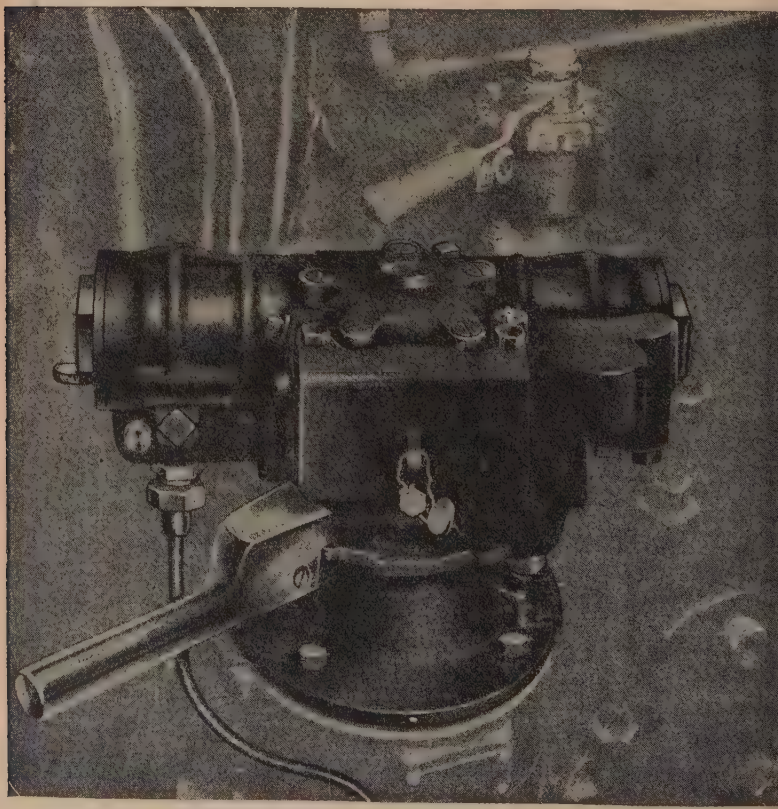


FIG. 6,722.—Actuator applied to engineer's brake valve.

Circuits.—Having described the principles upon which the operation of the circuits are based, the purpose of the following paragraphs is to describe actual application of typical circuits in the operation of the system. These circuits are:

1. Wayside circuits; 2. Locomotive circuits.

Wayside Circuits.—In this system an inductor is placed at every signal and the circuits controlling it are simple. It is only necessary to have the circuits so arranged that when the signal gives a restricting indication the coils of the inductor are open and when the signal is in the clear position the coils of the inductor are closed.

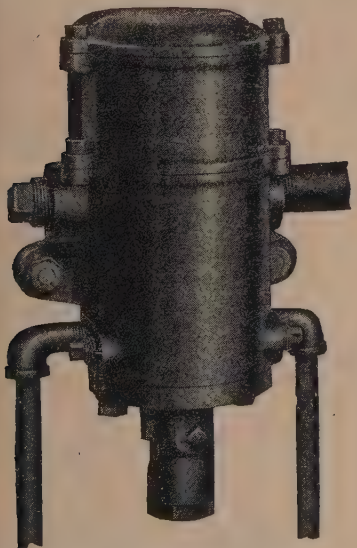


FIG. 6,723.—Electro-pneumatic valve.

Fig. 6,724 shows typical wayside circuits for a three position normal clear signal system. The signal circuits shown in this figure are the well known polarized track circuits, but it does not matter what kind of signal circuits are used.

The circuits controlling the inductors will always accomplish the same thing; that is, open the inductor coils when a restrictive signal is displayed and close the inductor coils when a clear signal is displayed.

It will be noted at signal 3, which is in the clear position, that the coils of inductor R3, are closed by a circuit controller operated by the signal itself and by the relay which controls the signal.

It is not necessary that the inductor be controlled by contacts on both the signal and the relay which controls it, but this gives a check on the integrity of the signal indication and is generally considered good practice.

Either the contacts on the signal or the relay contacts may be used if desired.

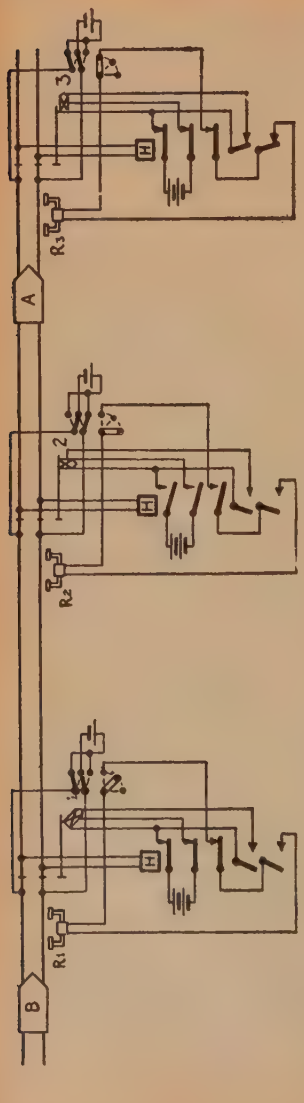


FIG. 6,724.—Diagram of wayside circuits.

At signal 2, which is at stop due to the presence of the train A, in the block, the coils of inductor R2, are open and consequently the receiver of a train passing inductor R2, would receive an impulse as previously described under heading "Transmission of Control Wayside to Locomotive."

At signal 1, which is at caution, the coils of inductor R1, are also open and the receiver of a train passing this signal would receive an impulse.

At signal 3, which is in the clear position, the coils of the inductor R3, are closed as mentioned before, therefore, the receiver of a train passing this signal would not receive an impulse.

If it be desired to check against the removal of an inductor, the track circuit may be bonded through the inductor housing as follows: One of the wires leading from the rail to the track relay at the signal location is carried to the tie supporting one end of the inductor and is anchored to the tie by means of a flexible connection, thence is bonded into the end of the inductor housing. A similar connection is made to the other end of the inductor housing and the wire carried back to the track relay.

The current operating the track relay must then pass through the inductor housing and if the inductor be dislodged from its support the wires being attached to the ties will be broken and the track relay

de-energized which will cause the signal ahead of the inductor to indicate stop and the signal in the rear to indicate caution.

If desired, the track battery, feeding the relay at the signal in the rear can be bonded through the inductor instead of the relay wire referred to, in which case the dislodgment of the inductor would place at stop the first signal in the rear and the second signal in the rear would show caution.

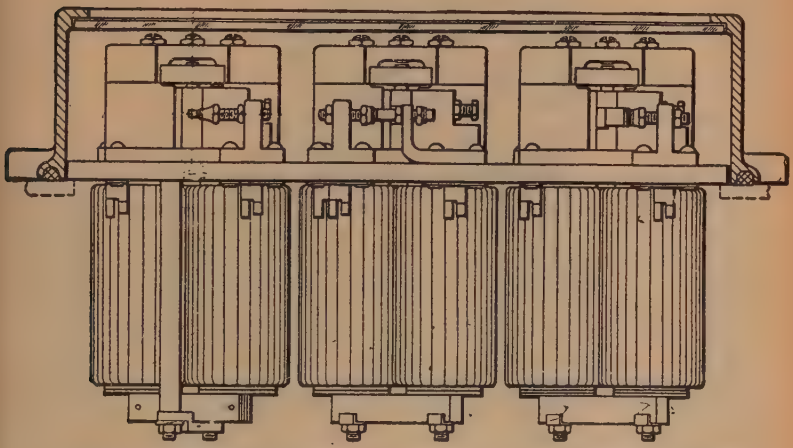


FIG. 6,725.—Construction and grouping of relays R1, R2 and R3. Relay R3 controls the electro-pneumatic valve.

Locomotive Circuits.—Typical circuits used on the locomotive are shown in fig. 6,730 and the following is an explanation of the symbols and a brief description of the contacts and magnets employed:

S.—Secondary coils of the receiver, see fig. 6,698.

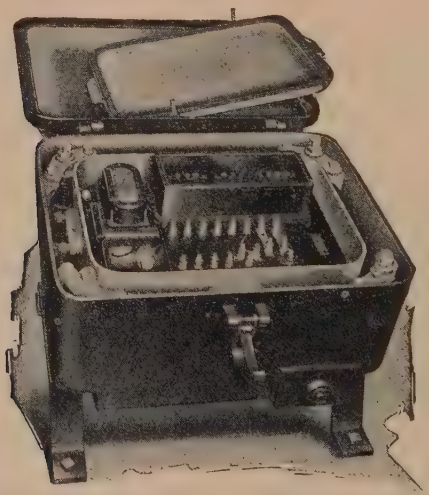
P.—Primary coils of the receiver, see fig. 6,698.

G.—Turbo-generator, usually the one used on the locomotive for lighting purposes.

EPV.—Electro-pneumatic valve controlling air to the brake applying actuator, see fig. 6,719.

R1.—Primary relay operated by the locomotive receiver, see fig. 6,698.

R2.—Secondary relay controlled by relay R1.



6,726.—Locomotive relays and housing. It will be noted that the relays and lamps together with their terminals, are mounted in an inner case which is floated on heavy springs and equipment with snubbers. The three relays are mounted on one base and the contacts are protected by a cover which has a glass top. The ballast lamps are protected by a wire mesh cover shown to the left of relays.

R3.—Relay controlling the electro-pneumatic valve. Fig. 6,725 shows the grouping and construction of relays R1, R2, and R3, and fig. 6,726 shows the relay housing.

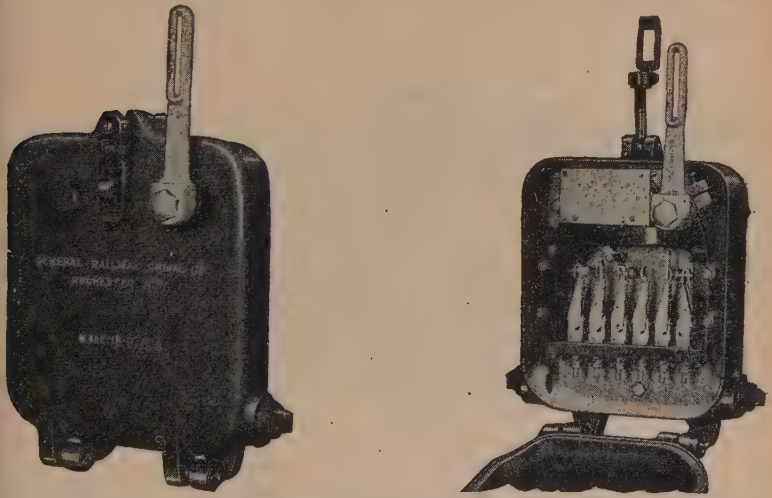
WV.—Electro-pneumatic valve controlling air to an audible signal, see fig. 6,723.

LL.—Ballast lamp used for correcting the fluctuation of the voltage of the turbo-generator. Any increase in current through the ballast lamp heats

the filament which reduces the current, or a decrease in current through the lamp cools the filament and increases the current, therefore, the ballast lamp serves to limit the current through the relays R1, R2, and R3, to the proper amount during a fluctuation in voltage of the turbo-generator.

Ack.—Acknowledging contactor, see figs. 6,727 and 6,728.

Cont.—When the operating handle is moved from its normal position, contacts X, and Y, are closed and a clockwork mechanism is started so that if the handle be held down for a longer period than 15 seconds contact Z, will open.



FIGS. 6,727 and 6,728.—Acknowledging contactor with cover, and open showing contact construction.

Reset.—Reset contactor, see fig. 6,729.

Cont.—Contacts 8, 9, 10 are operated by the reset contactor which is so located on the locomotive that it can be operated only when the engine is at rest.

In the diagrams the positions of parts are shown as they would be when the train is running subject to automatic control between impulse receiving points. Under these conditions the active circuits are as in fig. 6,730.

In fig. 6,730 the operation of the circuits is as follows:

When the receiver passes an inductor whose coils are closed as explained under the heading "Transmission of Control, Wayside to Locomotive," the current through the relay R1, is not materially changed, but when the receiver passes over an inductor whose coils are open, the current through relay R1, is decreased, so that its contacts are opened.

The opening of contact 2, of relay R1, deprives relay R2, of current and the opening of contact 3, of relay R2, deprives relay R3, of current.

The opening of contacts 6, and 7, of relay R3, deprives the electro-pneumatic valve of current and, as described under the heading "Brake Applying

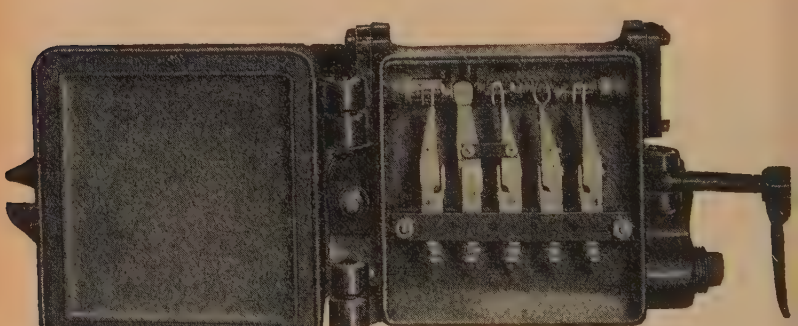


FIG. 6,729.—Reset contactor showing contacts.

Apparatus," a full service brake application results. The E.P. valve cannot then be supplied with current until relay R3, is again energized.

Relays R3, R1, and R2, are re-energized by the operation of the reset contactor as follows:

When contact 9, of the reset contactor is closed, relay R3, will receive current through the following circuits: From the positive side of the dynamo, wire B32, contact 9, of the reset contactor, wire P2, coils of relay R3, wire P1, ballast lamp L,L, wire P, primary coil of receiver, wire C, back to the negative side of the generator. This produces a drop in voltage across the coils of the relay R3, so that the relay R1, will be energized by the following circuit: Starting from the left hand side of the coils of relay R3, wire P2, contact 10, of reset contactor, wire S, coils of relay R1, wire P1, back to the right hand side of coils of relay R3. Having thus closed contact 2, of relay

R1, relay R2, will be energized so that contact 3, will be closed and the reset contactor can be returned to its normal position, thereby closing contact 8, which re-energizes the electro-pneumatic valve.

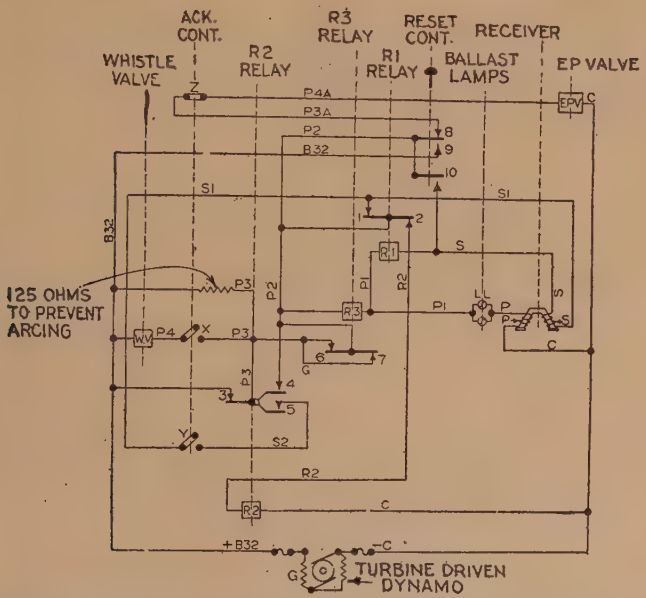


FIG. 6,730.—Locomotive circuit protection forward running only. Under the conditions shown, ***the active circuits are:*** P, primary coil of the receiver is energized by current flowing from the positive side of the dynamo through wire B32, contact 3, of relay R2, wire P3, contact 6 or 7 of relay R3, wire P2, the coils of relay R3, wire P1, the ballast lamp LL, wire P, through the primary coil of the receiver and wire C, to the negative side of the dynamo; R3, this relay is energized by the circuit last described; R1, this relay is energized by the drop in voltage across the coils of the relay R3, due to current flowing in the circuit last described. The circuit is as follows: Starting from the left hand side of the coils of relay R3, wire P2, contact 1, of relay R1, wire S1, secondary coil of the receiver, wire S, coils of the relay R1, wire P1, back to the right hand side of the coils of relay R3; S, the secondary coil of the receiver is energized by the circuit described above for relay R1; R2, the circuit which supplies current to the coils of relay R2, is traced as follows: Starting from the positive side of the turbine driven dynamo through wire B32, contact 3, of relay R2, wire P3, contact 6 or 7 of relay R3, wire P2, contact 2 of relay R1, wire R2, the coils of relay R2, and wire C, to the negative side of the dynamo; EPV, the electro-pneumatic valve is receiving current through the following circuit: starting from the positive side of the turbine driven dynamo, wire B32, contact 3, of relay R2, wire P3, contact 6 or 7, of relay R3, wire P2, contact 8, of reset contactor, wire P3A, contact Z, of the acknowledging contactor, wire P4A, the coils of the electro-pneumatic valve and wire C, to the negative side of the dynamo.

If, at the time the receiver passes over an inductor whose coils are open, contact X, on the acknowledging contactor is closed, relay R3, will not be opened, consequently the electro-pneumatic valve will not be deprived of current.

The circuit which holds relay R3, energized at this time, is as follows: From the positive side of the dynamo, wire B32, the coils of the whistle valve WV, wire P4, contact X, of the acknowledging contactor, wire P3, contact 6 or 7, of relay R3, wire P2, the coils of relay R3, wire P1, the ballast lamp LL, wire P, the primary coil of the receiver and wire C, back

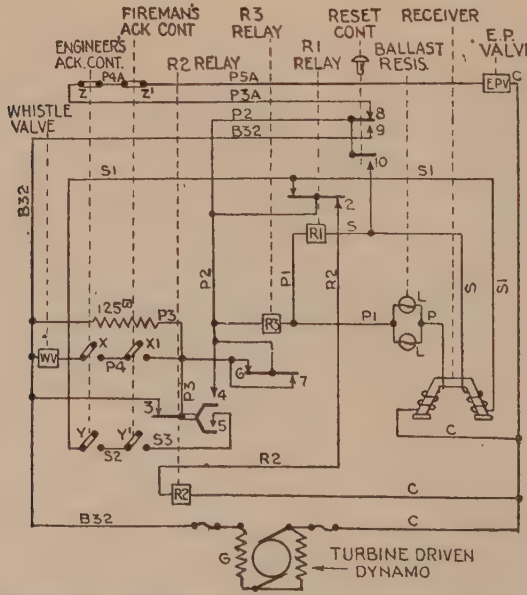


FIG. 6,731.—Typical locomotive circuit, forward running only, requiring acknowledgment by engineer and fireman.

to the negative side of the dynamo. With contact X, of the acknowledging contactor closed and contact 3, of relay R2, open, energy passes through the audible signal WV, causing a blast of the whistle. The blast, however, is of short duration because contact 3, of relay R2, is opened only momentarily and when closed short circuits the coils of the whistle valve WV.

When the receiver passes over an inductor under these conditions, that is, with contact X, of the acknowledging contactor closed, the impulse received will cause relay R1, to open, but since relay R3, is energized, as explained, relay R1, will immediately pick up. The momentary opening of relay R1, opens relay R2, which immediately picks up again.

Immediately after the relay R2, is opened, with the acknowledging contactor operated so that contact Y, is closed, relay R1, will be energized by the drop in voltage across the coils of relay R3, the circuit being as follows: Starting from the left hand side of relay R3, through wire P2, to contact 4, of relay R2, contact 5, of relay R2, wire S2, contact Y, of the acknowledging contactor, wire S1, secondary coil of receiver, wire S, the coils of relay R1, wire P1, back to the right hand side of the coils of relay R3.

Energizing relay R1, closes contact 2, of this relay which again energizes relay R2, so that all of the circuits are restored to normal. It will be noted that if the contacts X and Y, of the acknowledging contactor are closed for more than 15 seconds, contact Z, will open. This will deprive the E.P. valve of current and cause an automatic brake application. It will also be noted that if the acknowledging contactor be not operated at the time an inductor is passed whose coils are open, circuits cannot be restored to normal until contacts 9 and 10, of the reset contactor are operated.

The resistance of 125 ohms is placed between wires R32 and P3, for the purpose of preventing excess arcing of the relay contacts.

Where a locomotive is to operate with automatic train control protection for both forward and backward running, it is equipped with a receiver on each side and a reversing switch is operated from an axle drive.

The reversing switch closes contacts to include the coils of the right hand receiver when the locomotive is running forward, or it operates to disconnect the right hand receiver and include the coils of the left hand receiver in the locomotive circuits when the locomotive is running backward. In this case two ballast lamps are used, one in series with the primary coil of each receiver; otherwise the circuits are the same as formerly described.

Instructions to Enginemen.—To acquaint the engineman with the essential characteristics of the train control apparatus with which he comes in contact, it is necessary to outline what will take place under certain conditions. Apparently, the most suitable means of instruction is by the use of questions and answers.

In addition to the explanations already given the following questions and answers will be found helpful on operation:

Ques. What happens when the following occurs: 1. When the turbo is shut down? 2. When the turbo delivers a pulsating current due to a swinging short circuit in wiring? 3. When a train control fuse blows?

Ans. An automatic brake application results.

Ques. Can the equipment be reset under the above conditions?

Ans. No.

Ques. What must be done to reset under the conditions mentioned above?

Ans. 1, The turbo must be kept running; 2, train control should be cut out; 3, blown fuses must be replaced.

Ques. How is train control cut out?

Ans. By manipulation of cock handle on left end of actuator as follows: 1, break seal on locking pin; 2, withdraw locking pin to disengage handle; 3, raise handle to vertical position.

Ques. Where is the air supply to RH, or small cylinder of actuator obtained?

Ans. It is obtained from main reservoir above the rotary in the brake valve.

Ques. Where is the air supply to LH, or larger cylinder of actuator obtained with the equipment cut in?

Ans. It is obtained from main reservoir tap through the air strainer, the E.P. valve energized and the double heading cock normal.

Ques. Where is the air supply to LH, or large cylinder of actuator obtained with equipment cut out?

Ans. It is obtained from main reservoir above the rotary in the brake valve through the control cut out cock in the vertical position.

Ques. Where is the air supply to LH, or larger cylinder of actuator obtained when double heading?

Ans. It is obtained from same main reservoir tap which feeds E.P. valve. It is necessary that double heading cock be closed.

Ques. Is the second engine of double header subject to automatic train control?

Ans. No.

Ques. What must the engineman of a second engine do when lead engine cuts off?

Ans. He must have his turbo running and must reset before opening his double-heading cock.

Ques. How does the engineman know when he can relatch handle with rotary?

Ans. When indicator on top of actuator points to R.

Ques. To what position must the brake valve handle be placed in order to relatch?

Ans. The full service position.

Ques. A manual emergency application has been made following an automatic service application, what is the relatching position?

Ans. Slightly beyond the service position toward emergency.

Ques. What is the correct manner of operating reset contactor?

Ans. The button must be pressed for at least 2 seconds.

Ques. Can brake valve handle be relatched while reset contactor is being operated?

Ans. Not until reset is released to normal position.

Ques. In what position can the actuator cut out cock handle be sealed?

Ans. Only in the horizontal or cut in position.

Ques. If the acknowledger be operated continuously for more than 15 seconds what takes place?

Ans. At approximately 15 seconds an automatic brake application will result.

Ques. Will the whistle blow when passing an inductor under the above conditions?

Ans. Yes, provided the acknowledger is still pulled down and the indication of the roadway is still caution or stop.

Ques. Is it necessary to reset under the conditions described in the two preceding questions?

Ans. No.

Ques. An automatic brake application is received passing a proceed wayside signal. What should be done?

Ans. Reset. Acknowledge the next signal and if the whistle blow and signal be clear, it indicates that engine apparatus is at fault. Full report should be made to cover. If, however, the whistle do not blow when acknowledging the next proceed signal, it indicates that the inductor previously passed and at which the automatic application was received is at fault. Report should so state.

Ques. Is it possible that loose rails lying along the track in the approximate position of the inductor could cause an automatic brake application?

Ans. Yes—loose rails should, therefore, not be higher than the main track.

Ques. Is it necessary to acknowledge at inductor locations when backing against the current of traffic?

Ans. Yes.

Ques. If an automatic application of the brakes result from a broken air pipe, in the train control system, what should be done?

Ans. Plug the pipe, and if unable to relatch actuator, cut out train control.

Ques. Should the train control be cut out because of a leak in the copper piping?

Ans. It requires quite a leak to offset the differential in the actuator pistons. Train control should not be cut out unless

the leak is sufficient to overcome the differential in the actuator or unless the engineman cannot repair or close the leak.

NOTE.—The three questions following apply to equipments having actuators with the R, L, R, valve used in connection with a reduction reservoir for limiting the brake pipe reduction.

Ques. If the blow down be not limited, where would the trouble be?

Ans. The back pipe on right hand cylinder of actuator is broken. This is the pipe which leads to the reduction reservoir.

Ques. If the back pipe on the right hand cylinder of actuator be broken should it be plugged?

Ans. No.

Ques. If the front pipe on the right hand cylinder of actuator be broken what must be done? This is the pipe which connects to the equalizing reservoir.

Ans. The pipe must be plugged and a brake pipe reduction must be obtained by moving the brake handle toward the emergency position as far as may be required.

Typical Form of Instructions

(to enginemen)

Wayside Equipment

1. Inductor Location.

Inductors are located outside the right hand rail and approximately 70 ft. from each home signal, not including dwarf signals, governing entrance to a block in the direction from which trains normally approach such signals.

Engine Equipment

2. Receiver.

Receiver is mounted on the right side of the forward tender truck.

3. Actuator.

Actuator is mounted on automatic brake valve. When an automatic brake pipe reduction occurs, the actuator disconnects the brake valve handle on rotary valve and moves rotary valve to service position. When arrow on actuator points to R, running position, the brake valve handle can be relatched by moving to or slightly beyond service position. The handle of automatic brake valve is operative to manually apply brakes at all times.

4. Cut out Cock.

Cut out cock is provided on left hand actuator cylinder. When cut out cock handle is horizontal, automatic train stop is operative; it must be sealed in this position. When handle is vertical, automatic train stop is cut out.

5. Double Heading Cock.

Double heading cock when closed cuts out automatic train stop; this cock must be closed on all engines except the engine operating the train brakes.

6. Dynamo.

The headlight dynamo provides current for the operation of the automatic train stop and engine lights. Bright cab lights indicate there is sufficient voltage for the operation of the automatic train stop.

7. Main Reservoir Pressure.

For proper operation of automatic train stop, main reservoir must be maintained at designated normal pressure.

8. Forestalling Lever.

Forestalling lever is provided in engine cab which, when held in forestalling position, will prevent automatic brake pipe reduction when passing over inductor at signal which gives indication other than indication as determined by operating rules.

9. Reset Button.

Reset button, for re-establishing control of rotary valve so engineman can release after an automatic brake pipe reduction, is located on the right and near rear of tender frame.

10. Forestalling Whistle.

This is located in the engine cab. The stopping of the sounding of whistle is an indication that automatic train stop impulse has been received and forestalled by operation of the forestalling lever.

At Engine Terminal

11. Before Taking Engine out for Road Service.

1. See that cut out cock is sealed.

2. Start head light dynamo. Dynamo must be kept running continuously with throttle wide open when automatic train stop is cut in.

3. Press reset button for two seconds to set up automatic train stop apparatus.

4. Start air compressor. When pressure is 25 lbs. or over and indicator is at R, running position, move automatic brake handle to service position, or slightly beyond, then to running position.

5. Apply and release brakes to determine if working properly.

6. Move engine over test inductor at not less than 2 miles per hr. without forestalling, to determine if brake application be made. Operate reset button after engine has been brought to a stop.

7. Move forestalling lever to forestalling position while again passing over a test inductor to determine that whistle will sound and no brake pipe reduction is made.

8. If equipment fail to operate as intended, engineman must report to proper authority before departing.

Road Operation

12. Automatic Brake Application.

Automatic brake pipe reduction will occur when passing over inductor at signal which gives indication other than indication as determined by operating rules unless engineman holds lever in forestalling position until receiver is passing over the inductor and whistle has stopped sounding. Brake pipe reduction will occur if lever be held in forestalling position more than fifteen seconds continuously.

13. Forestalling.

1. When passing over inductor at signal displaying the indication as determined by operating rules.

2. Engineman must forestall at each inductor: *a*, When passing over inductor in making back up movement against the current of traffic; *b*, when running forward and pushing cars; *c*, in an emergency when double heading and automatic brakes are being operated by the second engine.

3. Engineman must not forestall until after signal indication has been observed and obeyed when passing over inductor at signal displaying other than the indication as determined by operating rules.

14. Automatic Brake Application and Release.

When automatic brake pipe reduction occurs, it will continue until the train is brought to a stop, after which the reset button must be pushed for two seconds and the button then released; the automatic brake valve handle must then be moved to, or slightly beyond, the full service position so as to relatch the handle with the rotary valve after which the brakes may be released by operating the brake valve handle in the usual manner.

15. To Cut Out Automatic Train Stop.

To cut out automatic train stop, due to failure of apparatus to operate properly, break seal on cut out cock handle, pull pin out and turn handle to the vertical position.

16. Broken Pipes.

If pipes to actuator cylinder, double heading cock or E.P. valve should break, the end toward source of air supply must be plugged, automatic train stop cut out and automatic brake valve latched up before proceeding. If branch of main reservoir pipe leading to side outlet of double heading

cock should break, the end toward the source of supply must be plugged; automatic train stop must be left cut in unless necessary to close double heading cock in which case automatic train stop must be cut out.

17. Reports.

If necessary to break seal on cut out cock, or, in the event of improper automatic train stop operation, report must be made. Defects in apparatus must be reported, and seals, if broken, turned in with reports which are made on special forms.

18. Operating Rules.

The use of the automatic train stop system does not supersede nor dispense with the use or observance of signals as prescribed by the rules in the book of "Rules for the Government of the Operating Department" by special instructions in the current time table, or bulletin order; nor does it modify the permissible maximum speed specified by bulletin order, or by special instructions in the current time table.

TEST QUESTIONS

1. *What is the object of automatic train control?*
2. *What is the penalty for failing to acknowledge restrictive signals?*
3. *What are the two parts comprising the device between the wayside and the locomotive?*
4. *How is a receiver mounted?*
5. *How does the receiver work?*
6. *Of what does the brake applying apparatus consist?*
7. *What is the actuator?*
8. *What is the purpose of the actuator?*
9. *What is the acknowledger?*
10. *What is the purpose of the acknowledger?*
11. *What is the purpose of the reset contactor?*
12. *What is the electro-pneumatic valve?*
13. *What is the whistle valve?*
14. *Draw diagrams showing operations of the actuator.*
15. *Describe the wayside circuits.*
16. *Draw diagram of the locomotive circuits.*
17. *Explain at great length the operation of the system.*
18. *What happens when the following occurs: 1, when the turbo is shut down; 2, when the turbo delivers a pulsating current due to a swinging short circuit in wiring; 3, when a train control fuse blows?*
19. *How is train control cut out?*

20. *What must the engineman of a second engine do when lead engine cuts off?*
21. *How does the engineman know when he can relatch handle with rotary?*
22. *To what position must the brake valve handle be placed in order to relatch?*
23. *If the acknowledger be operated continuously for more than 15 seconds what takes place?*
24. *Should the train control be cut out because of a leak in the copper piping?*
25. *If the front pipe on the right hand cylinder of actuator be broken what must be done?*

CHAPTER 151

Maintenance of Signal Systems

It may be said of any system of signaling and interlocking that *the system is as safe as its maintenance*. Efficient maintenance therefore, must consist in the rigid adherence to a carefully planned program of systematic inspection and testing for the detection of any tendencies to failure on the part of apparatus.

It must further consist in the necessary adjustment, replacement or repair which will preclude the possibility of any failure or derangement. Such a program can be discussed only in a general way since the frequency of inspection and the nature of the testing must depend upon the type of equipment, of the particular system, and the character and density of the operated traffic.

Points on Maintenance

Safety Measures.—1. The properly maintained signal system will provide for all devices being under lock and key to prevent tampering by unauthorized persons, and so that leverman or others without authority will not be permitted access to devices which might be manipulated to circumvent the restrictions imposed by interlocking equipment.

2. Those appliances to which the leverman is given access in an emergency are sealed, the breaking of a seal being a check on emergency procedure

Sealing irons, keys, etc., are in the possession of the maintainer in charge of the plant and it is his duty to see that all equipment is properly locked and that all seals are intact.

Inspection and Tests.—1. It is good practice for each section of block signals and interlocking to be inspected at least every two weeks.

2. Every part of the equipment should come under the observation of the inspector or maintainer who should take careful note of all parts which show evidence of wear or are in immediate need of replacement.

3. The equipment should be subjected to tests herein described, or other necessary physical or electrical tests which will assist in the determination of its condition whenever this is doubtful.

4. A large percentage of signal failures is due to defective track circuits.

Particular attention should therefore be given to track circuit equipment such as signal rail bonds, jumper connections, track relay and battery leads to track, as well as transformer leads and impedance bond connections where *a.c.* track circuits are employed. Resistance tests will verify the effectiveness of rail connections.

5. Insulated rail joints should be inspected to see that they are properly insulating the rails of adjacent track sections.

6. Where necessary, the megger test for insulation resistance should be applied.

The megger is connected from rail to rail across the joint when readings should be of satisfactory value for the insulating material of the joint and the thickness thereof.

7. Tests to ascertain that automatic block signals are operating properly are carried out by setting up conditions along the

track which would be similar to the occupancy of signal block sections by a train.

This is accomplished by shunting out the respective track relays and observing that automatic signals immediately in the rear of shunted section are giving the proper indication, and where automatic train stops are a part of the equipment as in rapid transit railways, that the stop arms are assuming the stop and clear positions in accordance with train stop control circuit plans.

8. The stop arms should be checked for alignment with relation to track to see that when in the stop position they will engage positively with the tripping device on a train or car, and operate to trip the train.

9. Inspection should be made of all moving mechanical parts to see that they are properly lubricated and that all screws, bolts, nuts, cotter pins, etc., are securely fastened.

10. The foregoing should be carried out through all interlocking territory as well as block signal territory.

11. At interlockings, all track switches should be carefully examined to see that all switch throw rods and front rods are properly adjusted so that switch point rails are correctly lined up with stock rails when the switch is in either the normal or reverse position, and that lock rods are carefully adjusted to properly engage with locking plungers of switch mechanisms.

12. At interlocking plants careful inspection and frequent service tests of electric locking are imperative to the safe operation of the plants.

Lever locks of the plunger type should be inspected, cleaned and tested every day to insure that dirt or other foreign substance will not prevent the lock dropping by gravity.

13. Test each lock by putting on and taking off current several times to see that the lock works properly.

If proper its operation will be quick and sharp.

14. All releases, the design of which might allow them to stick in one position and destroy their effectiveness, should also be inspected every day.

15. The maintenance of an interlocking machine consists principally in keeping the machine clean, all connections tight, and of wiping with an oiled rag at frequent intervals all parts that are liable to rust.

16. A high grade oil should be used when cleaning the mechanical locking of an interlocking machine.

17. Lever operation of the various functions controlled, may generally be said to be a good check on the condition of the interlocking machine, since completed operation of the interlocked functions gives assurance of the machine's integrity as the central controlling element.

18. It is good practice to anticipate the possibility of loose connections, etc., and at frequent intervals to inspect the different connections, contact springs, and various mechanical parts of the interlocking machine to insure that all parts are in the best condition.

19. Attention should be given to all other apparatus forming part of the interlocking system such as relays, annunciators, indicators, time locks, screw releases, bells, etc.

20. Careful attention should always be given to primary batteries to insure that they at no time approach a state of exhaustion, and to storage batteries as a check that they are in good condition and sufficiently charged to render the service which is required of them.

TEST QUESTIONS

1. *Upon what does the safety of an interlocking system depend?*
2. *How is efficient maintenance carried out?*
3. *What should be provided to prevent tampering by unauthorized persons?*
4. *What devices should be sealed?*
5. *What does the breaking of a seal indicate?*
6. *Who has charge of sealing irons, keys, etc.?*
7. *How often should each section of block signals and interlocking be inspected?*
8. *When inspecting, what memorandum should be made by the inspector?*
9. *What is the cause of a large percentage of signal failures?*
10. *How are the track circuits maintained in perfect condition?*
11. *How is the effectiveness of rail connections verified?*
12. *For what should rail joints be tested?*
13. *How is the megger test made?*
14. *How are tests made to ascertain that automatic block signals are operating properly?*
15. *For what should stop arms be checked?*
16. *In testing moving mechanical parts, what should be noted?*
17. *What tests should be made at an interlocking plant?*
18. *How often should lever locks of the plunger type be inspected?*
19. *What is the indication that a lock is working properly?*

20. *How often should releases which are liable to stick in one position, be inspected?*
21. *Of what does the maintenance of an interlocking machine consist?*
22. *What is a good check on the condition of the interlocking machine?*
23. *Name one piece of apparatus that should always receive special attention.*

CHAPTER 152

Electric Elevators

(Classification)

The ever increasing height to which buildings are being erected has resulted in the development of elevators and the introduction of numerous types to meet the requirements of a great variety of service conditions.

These numerous types may be classified:

1. With respect to service, as:

   a. Passenger;

   b. Freight { for hotels; apartments; stores, etc.

   c. Special { "sidewalk"; garage. "energy"

   d. Combination (mixed passenger and freight).

2. With respect to capacity, as:

   a. Light duty;

   b. Medium duty;

   c. Heavy duty;

   d. Extra heavy duty.

3. With respect to speed, as:

   a. Low speed;
   b. Medium speed;
   c. High speed.

4. With respect to the power unit (elevator machine), as:

   a. Drum;
   b. Traction.

5. With respect to the location of the power unit, as:

   a. Over mounted;
   b. Under mounted.

6. With respect to the electric current, as:

   a. Direct;
   b. Alternating.

7. With respect to the motor drive, as

   a. Gearless;
   b. Geared.

8. With respect to the rope drive, as:

   a. Drum;
   b. Traction.

9. With respect to the cable transmission (method of roping) on traction elevators, as:

   a. Half wrap;
   b. Full wrap.

10. With respect to the control, as:

    a. Semi-magnetic;
    b. Full magnetic;
    c. Rheostatic;
    d. Variable voltage;
    e. Inductor;
    f. Two speed;
    g. Push button;
    etc.

11. With respect to the method of operating the control, as:

    a. Semi-magnetic;
    b. Full magnetic.

12. With respect to the basic principle of the control, as:

    a. Rheostatic;
    b. Variable voltage.

13. With respect to the method of operating the elevator, as:

    a. Manual;
    b. Push button;
    c. Signal;
    d. Dual.

NOTE.—***A large elevator installation.*** The cost of installing elevators in the higher sky-scrapers is indicated by the report that $2,900,000 will be spent for sixty-six elevators in the eighty-five-story Empire State Building which will rise on the site of the old Waldorf-Astoria Hotel at Fifth Avenue and Thirty-fourth St., New York City. This shows an average cost of $43,500 for one elevator. Contract for the equipment is the largest single award of its kind ever made. The old hotel has now been completely demolished, and work is progressing rapidly on the foundations of the new tower, which will be the tallest structure in the world when completed.

14. With respect to the velocity ratio between motor and car, as:

a. Direct drive (1:1);

b. 2:1 reduction;

c. Multi-reduction.

15. With respect to balancing the load, as:

a. Counter-balanced;

b. Compensated.

CHAPTER 153

Selection and Installation of Electric Elevators

The initial elevator problem is one of service; so many factors enter into this problem that each individual case must be considered as a separate problem in itself. However, some accepted general rules may be stated for the guidance of elevator selection.

Size and Shape of Car.—In planning an elevator installation, consideration should first be given to the size and shape of the elevator car. The conditions surrounding the design of the building usually determine the space available for the elevators, which, when the proper clearance allowances between the car and the walls are made, fix the size and shape of the car or cars, as the case may be.

There are, however, certain shapes of cars that are desirable and, where conditions permit, these should be adopted in order to obtain the highest operating efficiency in the moving of traffic

Experience has shown that the best shape for an elevator car is one having a wide front in conjunction with a shallow depth. The wide front permits of ample door openings, thus providing for a quick transfer of passengers at floor levels, while the shallow depth reduces to a minimum the delays at landings incident to crowded cars whereby the passengers at the rear are hindered from free egress by the number of people standing in front of them.

The size of the car is determined either from the number of passengers to be carried or by limitations in the building design, as mentioned previously.

In figuring the car area required for a given number of passengers, the usual practice is to allow a space of 2 sq. ft. per person. The maximum load capacity of the elevator is figured on a basis of 75 lbs. per sq. ft. which assumes the average weight of a passenger to be 150 lbs.

Elevator Speeds.—The measure for the speed of a car is *the number of feet the car will travel during the period of one minute.*

The speed at which an elevator *should* travel is determined by consideration of the size and height of the building in addition to the character of the service to be performed; that is, whether for passengers, freight or a combination of both. The usual American practice for the speed of elevators is as follows:—

Passenger Elevators

	ft. per minute
Private residences	100 to 150
Hotels and apartment houses:	
Up to 5 floors (inclusive)	100 to 200
6 to 10 floors	200 to 350

Passenger Elevators

(Continued)

Department stores:	ft. per minute
Up to 5 floors (inclusive)	100 to 200
6 to 10 floors	200 to 300
Office buildings:	
Up to 10 floors	250 to 450
10th floor and above	400 to 800

For extra heavy duty, it is customary to select a speed as low as is permissible considering the rise of the elevator in order that the horse power requirements of the motor will not be excessive. When such loads exceed 10,000 lbs. it is the usual practice to install sheaves on car and counterweight and pass the hoisting cables under these sheaves and then to their fastenings at the top of the hoistway. The elevator is then classed as a rope geared installation. This construction transfers one half of the moving loads from the machine directly to the framework of the building and permits the use of standard machines.

Notes on Elevator Speed

NOTE.—***For automatic push button service.*** 300 ft. per minute is usually considered the limit of speed, as the automatic elevator is inherently a time waster inasmuch as the person within the car has complete control and runs the car without regard to the floor demands.

NOTE.—***It should be understood*** that many state and city codes limit the speed of elevators to 600 ft. per min.

NOTE.—***In department store service*** where stopping at every floor is required for sales reasons, 350 ft. per min. is the maximum desirable speed because above this the car would not attain full speed between floors and therefore would give very inefficient operation; 250 ft. per min. is about the accepted correct average speed for this service.

NOTE.—***Freight elevators*** are generally installed in warehouses and large manufacturing plants and for any load. The speeds vary from 35 to 150 ft. per minute, the higher speeds being used in buildings where the distance from floor to floor is the greatest.

NOTE.—***Combination elevators*** are usually installed in buildings used for manufacturing purposes, and comply with all the regulations for passenger elevators. They generally run at a slower speed than elevators installed for passenger service and carry larger loads. The American practice for combination elevators is as follows:

	ft. per minute
Building up to 5 floors	50 to 100
Building 5 to 10 floors	100 to 200

Capacity of Elevators.—The capacity of passenger elevators varies from about 1,000 lbs. in residences to 5,000 lbs. in department stores, and from 2,000 to 3,000 lbs. in office buildings. The capacity determines the car size which should be of sufficient floor area to provide not over 75 lbs. per sq. ft. as before stated. This is standard practice in the U. S.

Number of Elevators Required.—The number of elevators required to supply a given service is difficult to determine accurately because each building is an individual problem in itself, due to the large variation in the demands such as internal traffic, insurance office traffic, consulting office traffic, etc. Accordingly, the results obtained in similar buildings are used as a basis of calculation.

The following method may be used as a guide for determining the number of elevators required in a building of known dimensions. The population can be estimated from the rentable area as follows:—

New York City	75 to 100 sq. ft. per person
Other large cities	100 to 130 sq. ft. per person
Small cities	125 to 150 sq. ft. per person

Total travel in feet if not known, can be estimated by assuming 17½ ft. for the first floor and 12½ ft. between other floors.

Floor area of car platform:

27 sq. ft. for 2,000 lbs. for medium height buildings.

33 sq. ft. for 2,500 lbs. for standard office building capacity.

40 sq. ft. for 3,000 lbs. for special service where a lift for safes is required or the time schedule of leaving the first floor is not a feature.

The normal capacity of a car in passengers without crowding

is determined by allowing 2 *sq. ft. per person including the operator*.

The estimated time for synchronizing the cars, loss in time due to accelerating and retarding, loading and unloading at the first floor is 27½ seconds. The estimated time for accelerating and retarding, loading and unloading for each floor above the first is 7 to 8 seconds, or, if positive door locks be used, 8 to 10 seconds.

The estimated time required to empty the building above the first floor usually ranges from 40 to 60 minutes.

Example.—The following is an example of an office building calculation for New York City:—

Rentable area above first floor.....190,000 sq. ft.

Travel first to 16th floors—all local.....192 ft.

Car capacity, 2,500 lb. 33 sq. ft.....15 persons

Speed of car.....550 ft. per min.
Positive door locks used.

Time required to empty building.....45 min.

Estimated stops per mile of travel.....150 stops

Estimated sq. ft. per person in building.....80 sq. ft.

Population of building = 190,000 ÷ 80.....2,375 persons

Number of trips to empty building = 2,375 ÷ 15.....159 trips

Time lost. Stops at first floor = 27.5 + 2.....29.5 sec.

Actual running time per round trip = $\frac{2 \times 192 \times 60}{550}$.....42 sec.

Total round trip travel = 2 × 192.....384 ft.

The average number of feet between stops = 5,280 ÷ 150..35 ft.

Number of stops above first floor = 384 ÷ 35 − 1.....10 stops

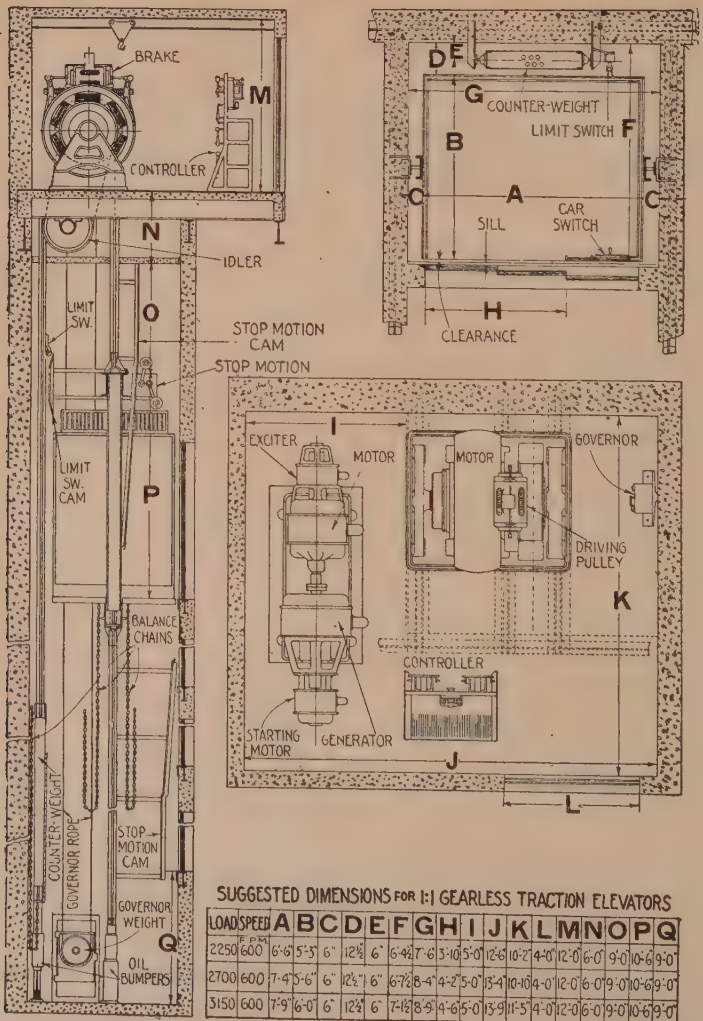
Stopping time above the first floor = (7½ + 2) × 10.....95 sec.

Total time of round trip = 29.5 + 42 + 95.....166.5 sec.

Total time of round trip.....2¾ min.

Time required for one elevator to empty the building = 159 × 2¾.....437 min.

Number of elevators required to empty building in 45 min. = 437 ÷ 45.....10 elevators



SUGGESTED DIMENSIONS FOR 1:1 GEARLESS TRACTION ELEVATORS

LOAD	SPEED F.P.M.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2250	600	6'-6"	5'-5"	6"	12½	6"	6'-4½	7'-6	3'-10	5'-0"	12'-6	10'-2"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6	9'-0"
2700	600	7'-4"	5'-6"	6"	12½	6"	6'-7½	8'-4"	4'-2"	5'-0"	13'-4"	10'-10"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6	9'-0"
3150	600	7'-9"	6'-0"	6"	12½	6"	7'-1½	8'-9	4'-6	5'-0"	13'-9	11'-5"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6	9'-0"

FIGS. 6,732 to 6.734.—A. B. See layout and recommended dimensions for 1:1 gearless traction elevators.

From the above it will be seen that during the rush hours ten elevators with a capacity of 2,500 lb. at 550 ft. per min. will give approximately 17 second service leaving the first floor. For the other hours of the day eight elevators will handle the traffic and give 20 second service from the first floor. If 15 second interval service be required eleven elevators will be necessary. This question of time interval must always be checked before definitely determining the number of elevators.

The foregoing calculations can only represent average conditions as the human element enters into the problem to a considerable degree.

For example, the time the car will be stopped at a floor varies from 4 to 12 seconds depending mainly on the characteristics of the people served.

Points on Elevator Selection.—To aid in selecting the proper elevator, the table on page 4,074 is given. This table shows the correct size of car for a given number of passengers and the plumb size of hatchway for the same car. Due to conditions imposed by the plans of a building, other shapes and sizes of cars than those shown in the table may of course be adopted.

The table also gives horse power output of motor. These figures are based upon the usual practice in elevator counterweighting and average efficiency of the completed installation. They are subject to variation in individual cases.

It is well to remember, however, that while the horse power figures are approximately correct for *d.c.* motors, these may be materially increased when *a.c.* motors are used; as the starting torque and horse power of *a.c.* motors vary with different manufacturers and largely determine the size selected for the duty to be performed.

NOTE.—***Service or capacity*** of elevators is affected by safety appliances such as door and gate interlocks inasmuch as the introduction of these devices increases the time for loading and unloading. Thus the extension of safety appliances tends to increase the number of elevators installed. This is unfortunate, but the safety consideration is so vastly important that the reduction of service efficiency is not to be deplored.

Table Giving Number of Passengers, Car and Hatchway Size, Load, Speed and Horsepower Output of Motor

No. Passengers	Size of Car		Size of Hatchway		Load	CAR SPEED IN FEET PER MINUTE							
	Width	Depth	Width	Depth		100	150	200	250	300	350	400	450
4	3′-2″	3′-2″	4′-0″	4′-0″	600	2.43	3.33	3.73	4.66	5.59	6.06	6.68	7.27
5	3′-7″	3′-5″	4′-5″	4′-3″	750	3.03	4.13	4.66	5.82	6.99	7.58	8.35	9.10
6	3′-11″	3′-8″	4′-9″	4′-6″	900	3.64	4.95	5.60	6.98	8.39	9.09	10.02	10.91
7	4′-3″	3′-11″	5′-1″	4′-9″	1050	4.25	5.78	6.54	8.16	9.79	10.61	11.70	12.72
8	4′-7″	4′-1″	5′-5″	4′-11″	1200	4.85	6.62	7.46	9.32	11.19	12.17	13.36	14.55
10	5′-2″	4′-6″	6′-2″	5′-9″	1500	6.07	8.26	9.34	11.62	13.99	15.15	16.70	18.20
12	5′-8″	4′-10″	6′-8″	5′-11″	1800	7.28	9.92	11.20	13.98	16.79	18.18	20.04	21.82
15	6′-6″	5′-3″	7′-6″	6′-4½″	2250	9.10	12.40	14.00	17.48	20.99	22.74	25.05	27.30
18	7′-4″	5′-6″	8′-4″	6′-7½″	2700	10.90	14.78	16.80	20.94	25.19	27.27	30.06	32.73
21	7′-9″	6′-0″	8′-9″	7′-1½″	3150	12.70	17.30	19.60	24.48	29.39	31.80	35.07	38.20
24	8′-4″	6′-4″	9′-4″	7′-5½″	3600	14.56	19.80	22.40	27.96	33.56	36.36	40.16	43.62

Installation Information.—Figs. 6,732 to 6,737 show typical layouts of elevator installations giving the clearance dimensions around the car; also the space requirements for shaft doors, etc., the over travel distances above and below the normal limits of car travel, and the desirable size of the machine room.

To illustrate, assume a load of ten passengers totaling 1,500 lbs. The table on this page specifies a car 5 ft. 2 in. × 4 ft. 6 in., and the finished dimensions of hoistway work out to the sizes shown. In this connection, it should be noted that an extra one inch is shown as an additional allowance for finished plaster on three sides of the hoistway.

In the case where two or more elevators run in the same hoistway, it is customary to divide the hoistway by an eight inch I beam placed at the floor levels to act as a support for the car guides; an allowance of 4 ins. should be made where such beams are used.

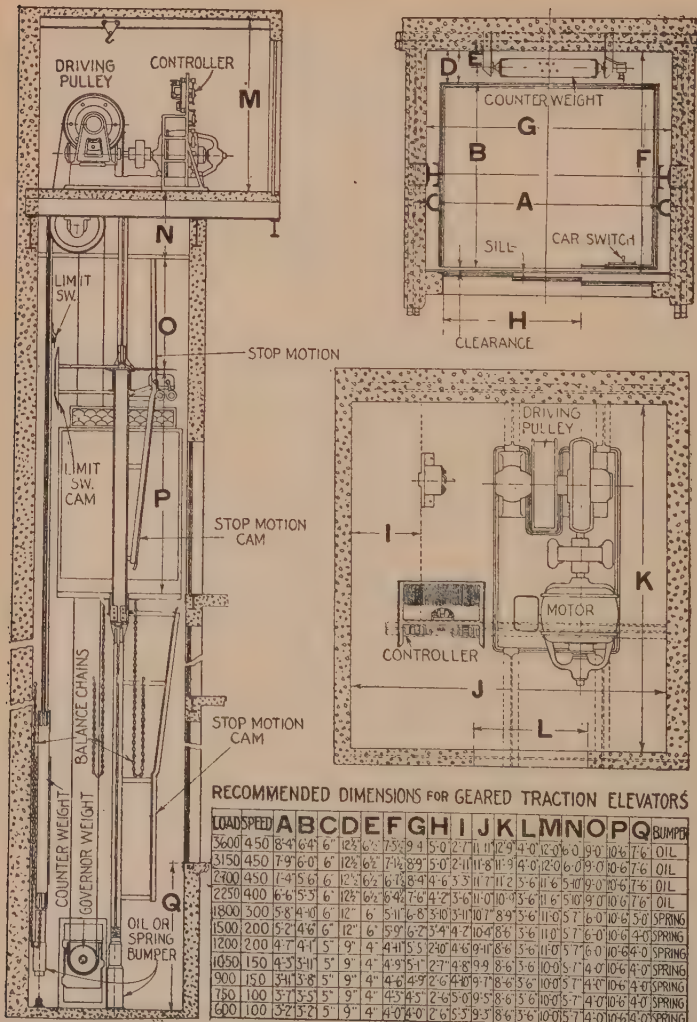
Assuming a car speed of 150 ft. per min. as suitable for this elevator, the size of the motor can now be determined. The table for 1,500 lbs. at 150 ft. per min. gives 8.26 horse power, which in standard sizes would fix the selection on a 10 horse power motor as ample to do the work specified. The elevator machine, of size suitable for the duty, can now be selected and its location determined.

There are several types of machines manufactured, each of which has its advantages and uses depending upon the service requirements and the conditions of installation.

Location of Elevator Machine.—Sometimes the elevator machine is located in the basement. Probably 98% of all new installations in the United States use an overhead machine installed in a room called the pent house at the top of the building. Basement installations are objectionable because they require much longer hoisting cables and more idler sheaves than for overhead machines; they occupy valuable space in the basement and in many cases the actual load on the building is greater. Placing the machine directly over the hoistway imposes a load on the building equal to the weight of the hoisting machine, plus the loads on the car and counter-weight ropes, whereas placing the machine below, imposes a load on the building equivalent to twice the loads on the car hoisting and counter-weight ropes. Therefore, if the hoisting engine weigh less than the combined loads on the car and counter-weight ropes, placing the machine overhead reduces the load on the building. This relation of weights often occurs.

The drum type machine is suitable for overhead location, and the traction type, single and double wrap are best adapted to basement location.

The single wrap traction in modified design may also be used in basement locations. The overhead location is desirable principally for the reason that the machine occupies a less valuable space in the building



RECOMMENDED DIMENSIONS FOR GEARED TRACTION ELEVATORS

LOAD	SPEED	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	BUMPER
3600	450	8'-4"	6'-4"	6"	12"	6"	7'-5"	9'-4"	5'-0"	2'-7"	11'-11"	2'-9"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6"	7'-6"	OIL
3150	450	7'-9"	6'-0"	6"	12"	6"	7'-1"	8'-9"	5'-0"	2'-11"	11'-8"	11'-9"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6"	7'-6"	OIL
2400	450	7'-4"	5'-6"	6"	12"	6"	6'-8"	8'-4"	4'-6"	3'-3"	11'-7"	11'-2"	3'-6"	11'-6"	5'-10"	9'-0"	10'-6"	7'-6"	OIL
2250	400	6'-6"	5'-5"	6"	12"	6"	6'-4"	7'-6"	4'-2"	3'-6"	11'-0"	10'-9"	3'-6"	11'-6"	5'-10"	9'-0"	10'-6"	7'-6"	OIL
1800	300	5'-8"	4'-0"	6"	12"	6"	5'-11"	6'-8"	3'-10"	3'-11"	10'-7"	8'-9"	3'-6"	11'-0"	5'-7"	6'-0"	10'-6"	5'-0"	SPRING
1500	200	5'-2"	4'-6"	6"	12"	6"	5'-9"	6'-2"	3'-4"	4'-7"	10'-4"	8'-6"	3'-6"	11'-0"	5'-7"	6'-0"	10'-6"	4'-0"	SPRING
1200	200	4'-7"	4'-1"	5"	9"	4"	4'-11"	5'-5"	2'-10"	4'-6"	9'-11"	8'-6"	3'-6"	11'-0"	5'-7"	6'-0"	10'-6"	4'-0"	SPRING
1050	150	4'-3"	3'-11"	5"	9"	4"	4'-9"	5'-1"	2'-7"	4'-8"	9'-9"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING
900	150	3'-11"	3'-8"	5"	9"	4"	4'-6"	4'-9"	2'-6"	4'-10"	9'-7"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING
750	100	3'-7"	3'-5"	5"	9"	4"	4'-3"	4'-5"	2'-6"	5'-0"	9'-5"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING
600	100	3'-2"	3'-2"	5"	9"	4"	4'-0"	4'-0"	2'-6"	5'-3"	9'-3"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING

FIGS. 6,735 to 6,737.—A. B. See layout and recommended dimensions for geared traction elevators.

and also because the hoisting ropes, subject to wear and replacement, are only one third the length as compared with those required by a basement machine.

In figs. 6,732 to 6,734 an outline of the elevator machinery is shown together with dimensions of the machine room.

In figs. 6,732 and 6,734 is shown a concrete slab under the machine base.

This construction is desirable as it forms a solid floor for the machine room, in place of the usual open iron grating and furthermore, acts as a barrier to the transmission of unavoidable sounds to other portions of the building.

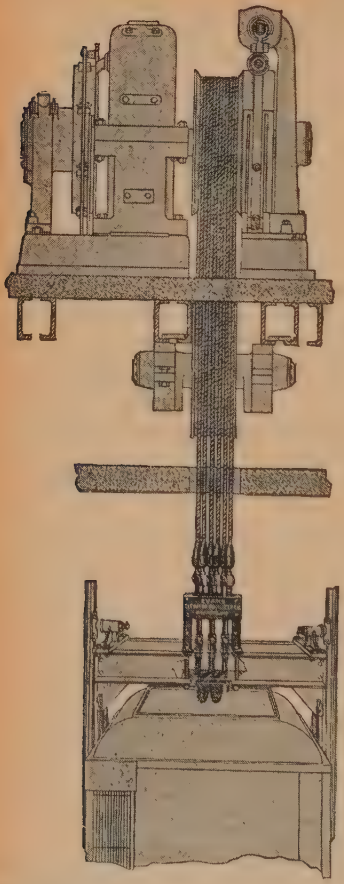
In apartment houses, hotels and hospitals where extreme quiet is required, the machine is often located in the basement on a solid concrete foundation. The elevator specifications require that the owner should provide supports for the overhead machine beams supplied by the elevator contractor.

Fig. 6,732 shows the height and location of these beams above the top floor landing. This height dimension is not fixed; it varies with different installations and is determined from the drawing which shows the height of car when at the top landing, the over travel clearance allowance between top of car and idler sheave, and the distance this sheave projects below the machine beams.

A considerable saving of space, and incidentally, wear of hoisting ropes, can be obtained by the elimination of the idler sheave.

This sheave with certain types of machines is required only when the distance between the centers of the car and counterweight is greater than the span of the driving sheave on the machine overhead. Limitations in design, however, fix the maximum diameter of the driving sheave or drum permissible on the different sizes of elevator machines.

The factors that have a bearing on the selection of the type of machine to use are as follows:



The utilization of the traction or friction drive principle for transmitting motion to an elevator car solved the problem of the high rise elevator so that now the height of a building is no longer a difficulty. The single wrap traction is particularly adaptable to cars where there is little deflection of the hoisting ropes. This drive has the advantage of giving longer life to the ropes as compared with the double wrap traction, but, on the other hand, the double wrap usually shows less wear on the grooves of the driving sheave.

NOTE.—***Properly installed traction elevators*** have the length of the lifting ropes so proportioned that when the car is resting on the bumpers at the bottom of the hatchway, the counter-weight is some distance below the overhead work and vice versa. As the driving power for the elevator car is obtained by friction between the ropes and the driving sheave, it is evident that when either the car or counterweight is resting on the bumpers the tractive effort is reduced to a minimum.

FIG. 6,738.—Evans equalizer attached to elevator. The object of this device is to equalize the tension in all the ropes. The equalizer also takes care of any differential travel caused by variable diameter of the grooves, or by oversize or undersize cables. $\frac{1}{32}$ in. variation in the diameter of the sheave grooves or in cable diameter will, with 20 turns of the sheave, as the car travels from top to bottom, create a variable travel of the cables at 2 ins. or more. Even if sheaves be perfect when installed, it is only a question of time until the groove diameters are worn to such an extent that the differential travel becomes irregular. This means that a few of the ropes carrying the load going in one direction transfer it to the other ropes going in the opposite direction.

TEST QUESTIONS

1. *What is the most important item in planning an elevator installation?*
2. *Name the various items which determine the size and shape of car.*
3. *What is the advantage of a car with a wide front?*
4. *What is the space allowance in the car per person?*
5. *How is elevator speed measured?*
6. *How is the desirable speed determined for a given installation?*
7. *What should the speed be for extra heavy duty?*
8. *What is the best speed for department store service?*
9. *What is the range of elevator capacity?*
10. *Can the number of elevators required for a given building be easily determined?*
11. *Give an example for determining the number of elevators.*
12. *Make a layout with recommended dimensions for* 1:1 *gearless traction elevators.*
13. *Mention a few points on elevator selection.*
14. *How is service or capacity of elevators affected by safety appliances?*
15. *Sketch a typical layout giving necessary installation information.*
16. *What is the customary arrangement where two or more elevators run in the same hoistway?*
17. *How is the size of motor determined?*
18. *Name two locations of the elevator machine.*
19. *What type of machine is suitable for overhead location?*

20. *Make a layout with recommended dimensions for geared traction elevators.*
21. *Where is the elevator machine located in apartment houses, and why?*
22. *What is the advantage of eliminating the idler sheave?*
23. *What are the factors that have a bearing on the selection of the type of machine to use?*

CHAPTER 154

Types of Elevator Machine

There is a great variety of types of *power unit* or *elevator machines* employed to drive electric elevators. With respect to the method of transmitting the power to the car ropes, elevator machines are divided into two general classes:

1. Drum;

2. Traction;

there being numerous types of each class.

An elevator machine consists essentially of *a motor, drum or traction pulley, brake and motor-drum drive.*

The drive may consist of a direct shaft connection between the motor and drum, or one of the numerous types of gearing. A comparison of these two types is shown in figs. 6,739 and 6,740, in which the important distinguishing features are emphasized.

Drum Elevator Machines—The word drum, as correctly used to distinguish one of the two general classes of elevator machines, means a *winding drum* as distinguished from what looks like a short drum; that is, a traction drum, the latter being simply a type of pulley or sheave. A drum then, is *a form of spool on which the ends of ropes are attached and around which they are wound and unwound in the operation of the car*, as shown in fig. 6,741. Note the difference between this drum and the traction pulley shown in fig. 6,742.

The principle of drum drive is shown in fig. 6,743.

In the operation of a drum elevator machine, power when applied to the driving gear, turning it in one direction, winds the ropes upon the

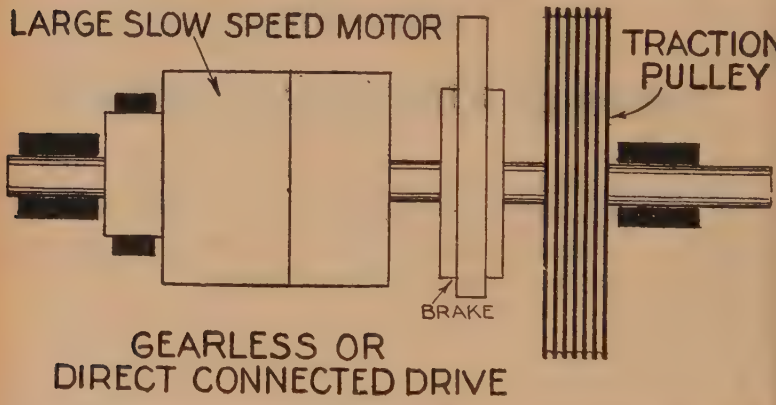


FIG. 6,739.—Elementary elevator machine with gearless or direct connected drive. A large slow speed motor is required.

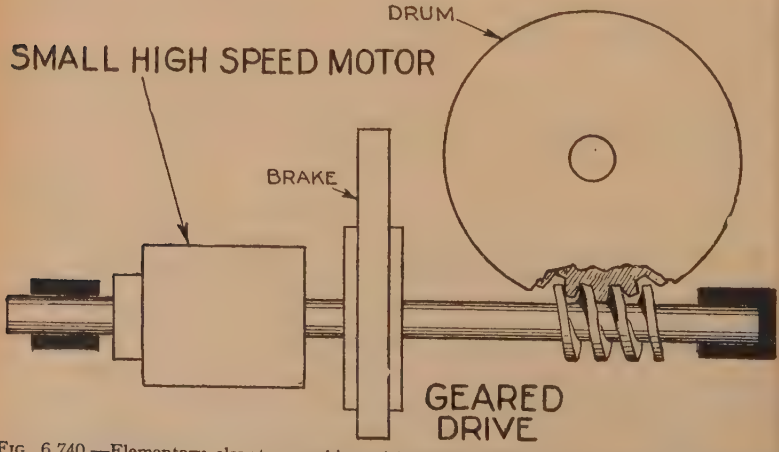
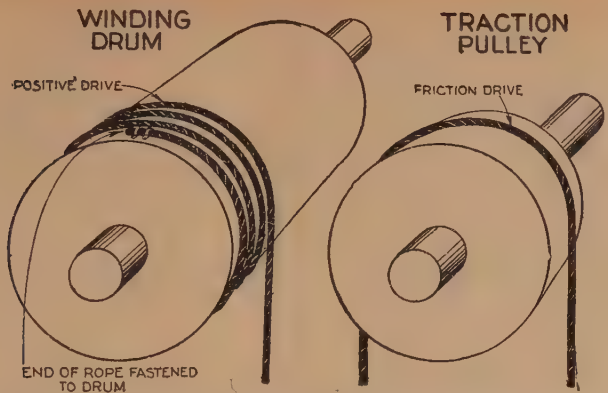


FIG. 6,740.—Elementary elevator machine with geared drive. Note the small high speed motor. With this type of elevator machine any one of several forms of gear may be used.



FIGS. 6,741 and 6,742.—The two types of drum used on elevator machines. *In construction,* grooves (not shown) are provided on both types of drum, *the grooves being spiral for drum elevators* and *straight* for *traction elevators.*

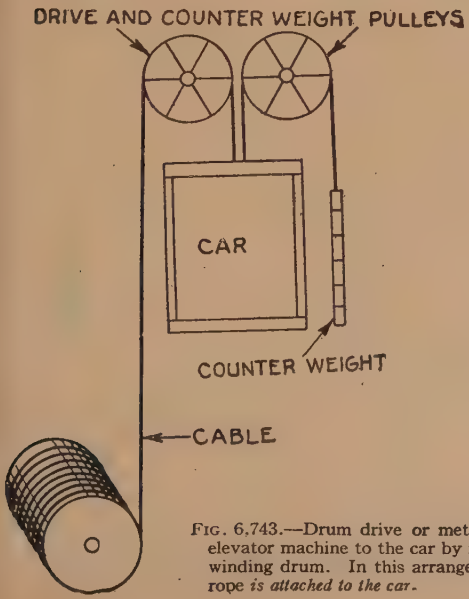


FIG. 6,743.—Drum drive or method of transmitting power from the elevator machine to the car by means of winding the hoist rope on a winding drum. In this arrangement the end of the counter weight rope *is attached to the car.*

drum and causes the car to ascend, and when the power is reversed, the drum turns in the opposite direction, paying out the ropes, and causing the car to descend.

The weight of the car is balanced by a counter-weight, thus reducing the energy to be expended in operating the car. Automatic devices, to be described later, are used to insure the proper and safe control of the movements of the car.

Sometimes the ends of the counter-weight ropes are attached to the drum as in fig. 6,744 instead of to the car, as in fig. 6,743. In the arrangement shown in fig. 6,744, when the hoisting ropes wind up, the counter-weight ropes unwind and vice versa.

The drum is machined with spiral grooves to guide the ropes.

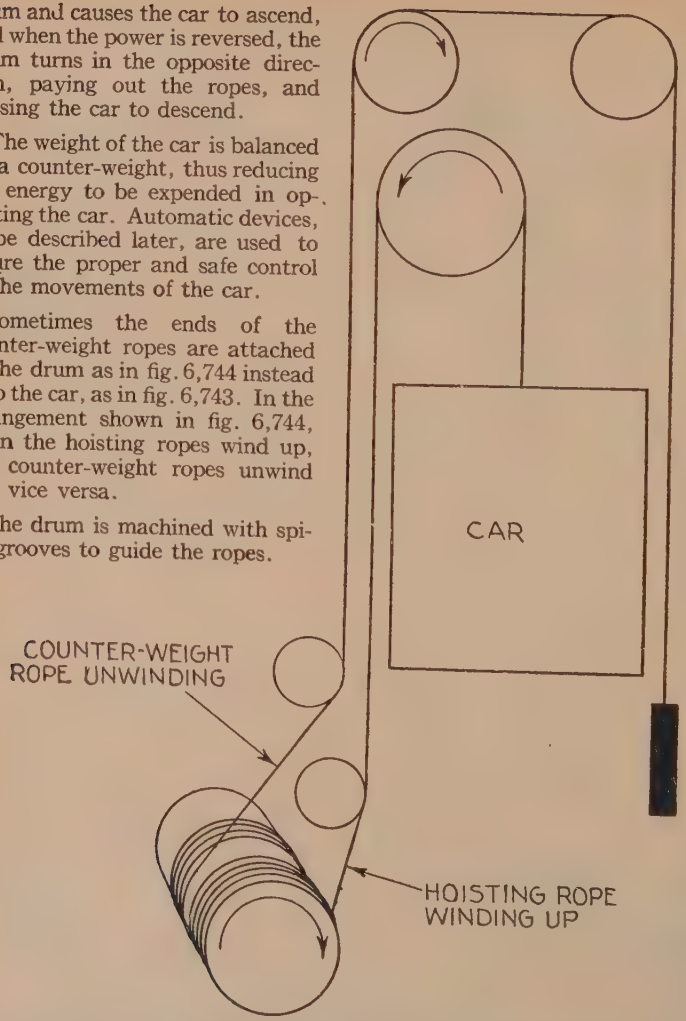


FIG. 6,744.—Drum drive arrangement in which the end of the counter-weight rope *is attached to the drum.*

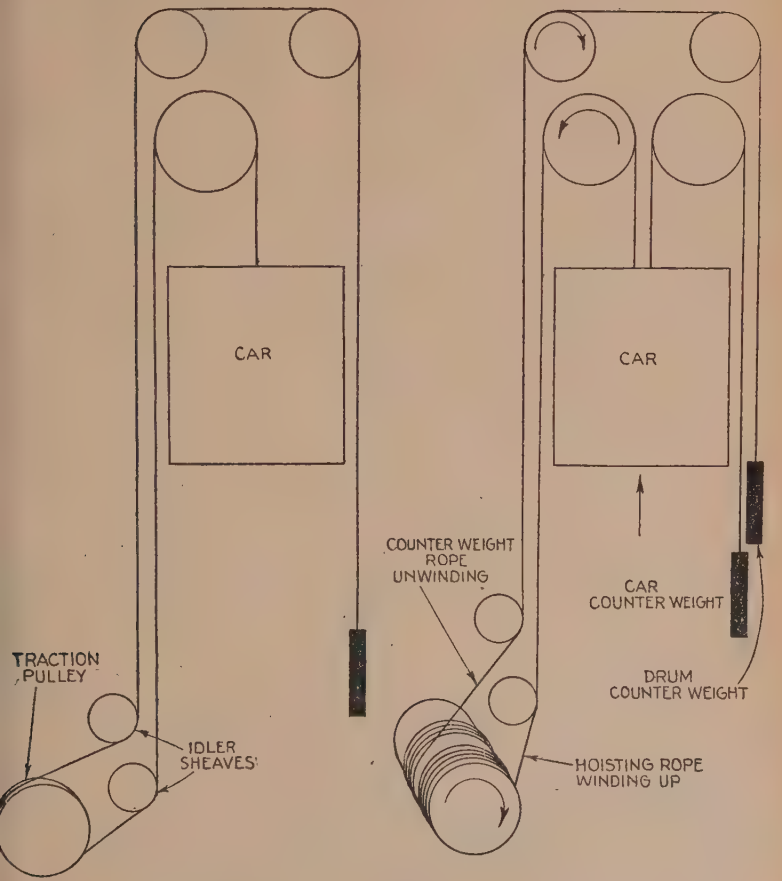


FIG. 6,745.—Rope drive arrangement for basement type V groove single traction elevator.

FIG. 6,746.—Drum drive arrangement having two counter-weights, one roped to the drum and the other to the car. This arrangement reduces the load on the drum and bearings and is used on large cars.

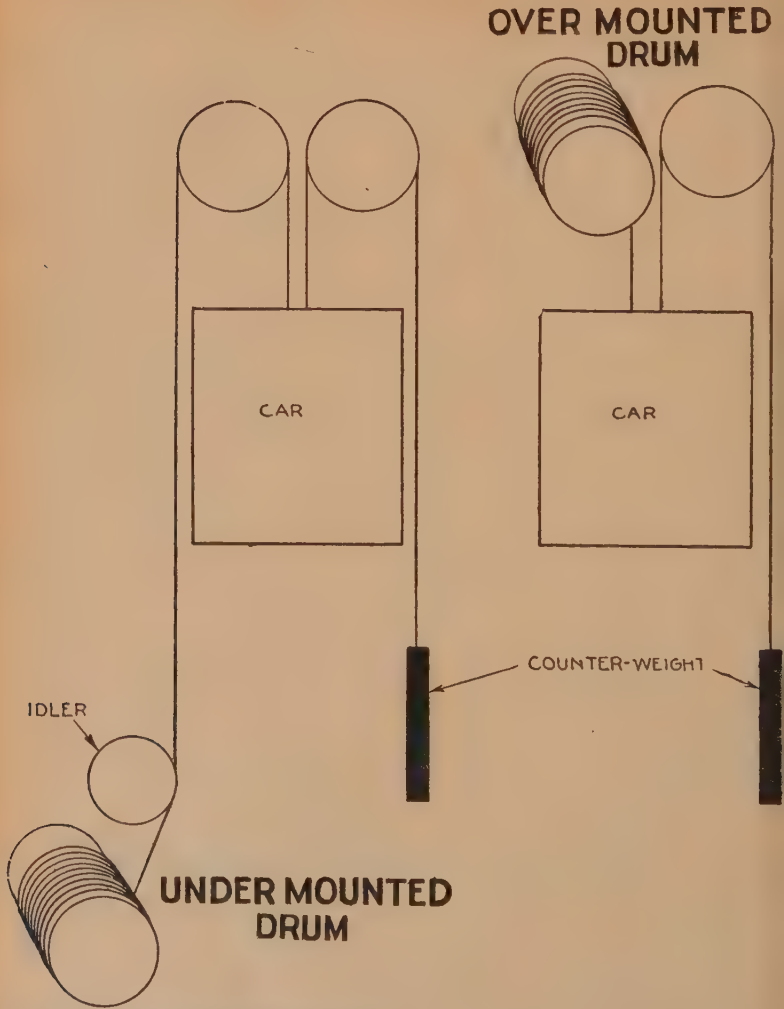


FIG. 6,747.—Under mounted drum elevator.

FIG. 6,748.—Over mounted drum elevator.

With respect to location, there are two types of machine, known as:

1. Over mounted;
2. Under mounted;

according to whether the machine is placed above the hoistway or in the basement.

The over mounted machine gives direct transmission; that is, no pulleys are required between drum and car, also the drum may be so located that one face of the drum is over the center of the car, and the other face over the counter-balance, thus allowing the car ropes to be fastened at one end of the drum and the counter-balance ropes at the other end of the drum grooves, the car ropes occupying the entire surface of the drum when the car is up, and the counter-balance ropes following alongside of them, occupying the entire drum surface when the car is down.

This arrangement transmits power with the minimum length of ropes.

If the drum type machine be installed overhead it will give remarkably long rope life because there is no possible rope creepage and the bending is always in one direction. However, if the machine be installed in the basement, reverse bends are necessary in the ropes and this materially reduces the rope life.

One reason for the decreased use of the drum machine is because it requires a modification of the machine for each installation, as the length of travel determines the length of the winding drum. Another bad feature is that should the terminal stops and overtravel limit switches fail to stop the car at the terminals, the machine may continue to travel and finally pull the ropes from their sockets.

Fig. 6,747 shows an elevator installation with under mounted type of drum machine. An over mounted drum machine with worm drive is shown in fig. 6,748.

Traction Elevators.—This type of elevator derives its name from the fact that motion is obtained *by means of the* **traction,** that is to say, *the friction existing between the driving pulley* and the hoisting ropes.

The ropes are not wound on a drum, but a continuous rope from the car to the counter-weight passes over a driving pulley.

The traction machine carries the hoist ropes over the hoisting sheave and down to the counter-weight and relies on the grip of the ropes on the sheaves to give enough traction to lift the load.

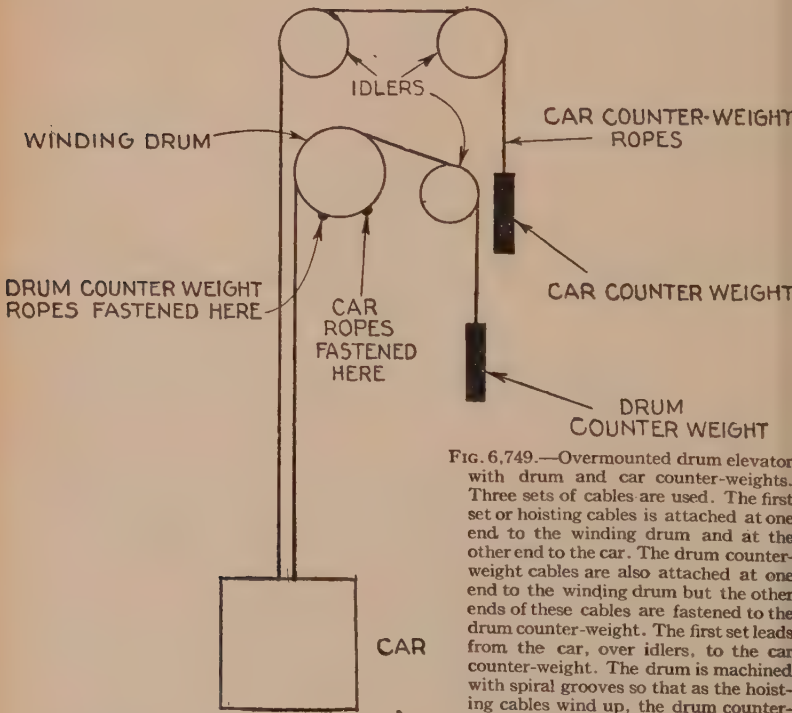


FIG. 6,749.—Overmounted drum elevator with drum and car counter-weights. Three sets of cables are used. The first set or hoisting cables is attached at one end to the winding drum and at the other end to the car. The drum counter-weight cables are also attached at one end to the winding drum but the other ends of these cables are fastened to the drum counter-weight. The first set leads from the car, over idlers, to the car counter-weight. The drum is machined with spiral grooves so that as the hoisting cables wind up, the drum counter-weight cables unwind.

Practically all elevators except a few low speed low lift machines today are the traction type. It is common to hear a gearless machine spoken of as a "traction machine," as though geared machines were not traction machines, but this is wrong, as a geared machine may be just as much a traction machine as a gearless machine.

There are two methods of roping known as

1. Half wrap (V groove);
   Figs. 6,759 and 6,760.
2. Full wrap (U groove).
   Figs. 6,755 to 6,758.

The term single wrap and double wrap are sometimes used respectively for half wrap and full wrap.

When hoist ropes lead over the driving, or traction sheave and down to the counter-weight, either straight or over an idler sheave, as in figs. 6,759 and 6,760, the grooves on the traction sheave are V shaped, to grip the sides of the rope, so a half wrap traction machine is frequently called a V groove traction. The V grooves cause the ropes to be pinched tightly,

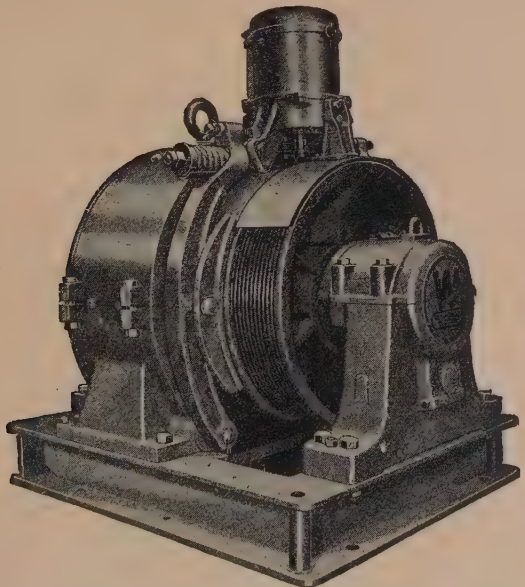


FIG. 6,750.—Westinghouse gearless traction elevator machine for high speed passenger service. A slow speed motor is used, having a grooved sheave wheel assembled on the armature shaft. The ropes which support the car and the counter balancing weights pass over the sheave wheel, giving the traction that moves the car. This type of elevator is accepted as the best for car speeds of approximately 400 *f.p.m.*. and higher because it is more economical in operation and all wear and vibration of gearing are eliminated.

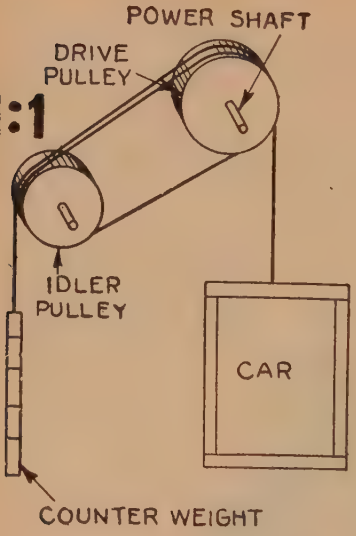


FIG. 6,752.—Direct (1:1) traction drive or method of transmitting power from the power unit to the car by means of frictional contact of the rope in passing one or more times around the drive pulley. This arrangement, since it does not employ a drum where size has to be considered, can be used for lifts of any height, and is the prevailing type today.

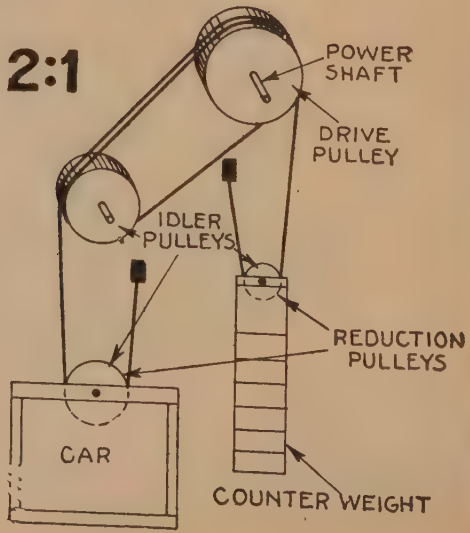
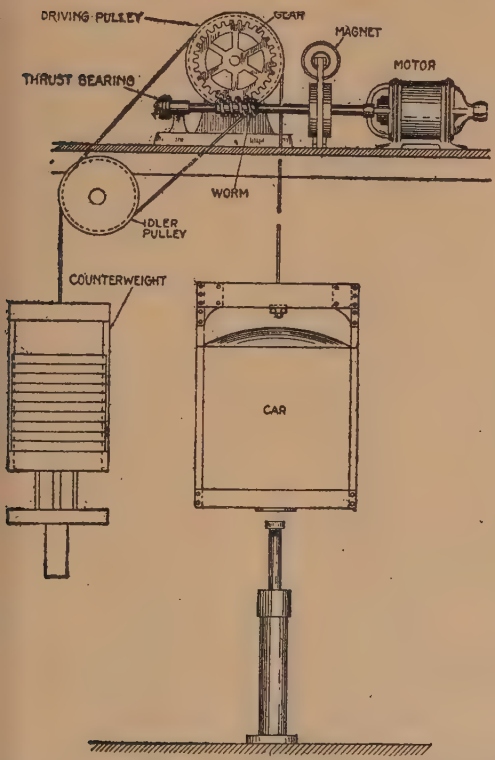


FIG. 6,753.—Geared, or 2:1 friction drive, or frictional contact transmission with reduction gear pulleys—a type used for moderate speed elevators.

due to the weight of the car and counter-weight. The advantage of this system is its simplicity, and long rope life is claimed for it, due to the reduced number of bends and the absence of slippage between the ropes and the sheave. The disadvantage lies in the tendency of the sides of the grooves to wear down and reduce the grip on the ropes.



For higher speeds, over 500 *f.p.m.* and sometimes for speeds 500 *f.p.m.* and below, the hoist ropes lead around the traction sheave for another half wrap and so down to the counter weight, as in figs. 6,752 and 6,756.

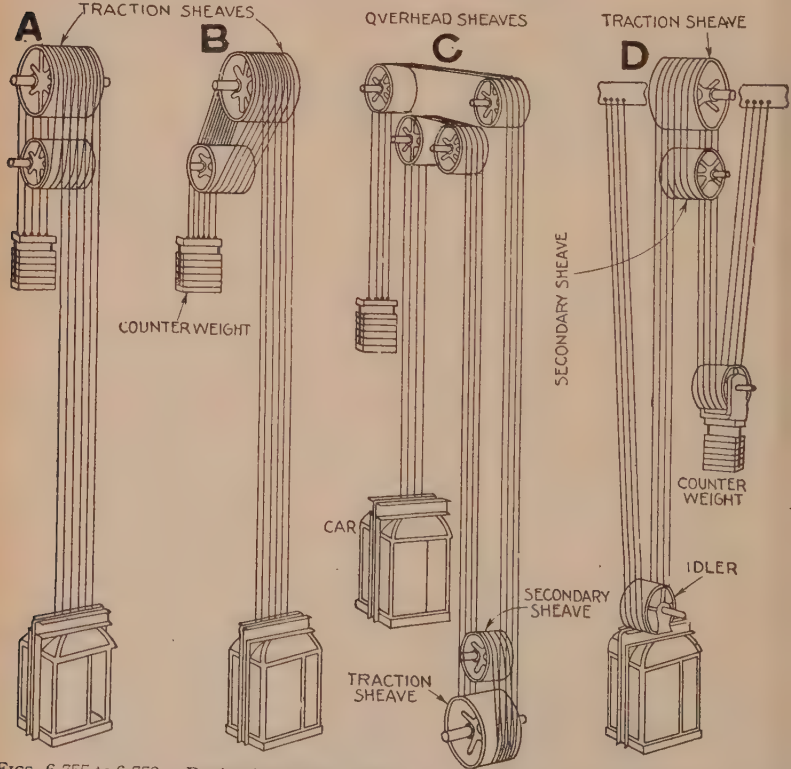
This is called full wrap or double traction. The grooves of the traction sheave of full wrap machines are U shaped, and such machines are sometimes called U groove machines.

There are two forms of the so called gearless traction elevators: the

FIG. 6,754.—Diagram of an overmounted traction elevator with multi-reduction or worm drive. The traction feature is identical with fig. 6,752. Attached to the driving pulley is a gear which meshes with the worm underneath, the latter being direct connected to the motor. Clearly, the worm gives a large velocity reduction permitting the use of a high speed motor. The magnetic brake being located to act on a brake pulley attached to the fast revolving motor shaft gives considerable braking power light grip on the brake pulley. The action of the single worm gear is such as to require a thrust bearing, as later explained in detail.

1 to 1 or direct drive type shown in fig. 6,752 and the 2:1 reduction type shown in fig. 6,753.

A third form of traction elevator known as a multi-reduction or worm drive is shown in fig. 6,754, the essential features of each being mentioned under the illustrations.



FIGS. 6,755 to 6,758.—Roping for full wrap traction elevators. This machine, cabled directly one to one, or two to one, has the advantage of being a standard stock machine for all lengths of travel. One possible objection to this type of machine is that the driving sheave bearing is required to take double load due to the double wrap necessary in this form of drive. This produces a somewhat lower efficiency than could otherwise be realized. Because of the round grooves the traction is limited but it does not change much with wear as it does in the case of the half wrap traction machine.

By comparing the three figures it is obvious that the direct drive machine (fig. 6,752) is suitable for high speed service; that the 2:1 reduction machine (fig. 6,753) is an adaptation of the direct drive type permitting of slower car speeds; the multi-reduction type (fig. 6,754) permitting the use of small high speed motor.

The traction type machine has the advantage of being more compact than the drum type, since a traction pulley is substituted for the larger drum and a single design may be used for buildings of greatly varying heights. It is inherently safer than the drum type machine, due to the fact that it will not over wind. Should the motor fail to stop, either the car or counter-weights will land at the bottom of the pit and the machine will lose its traction.

Roping.—The simplest roping or hitch is 1:1. See fig. 6,752. Here the peripheral velocity of the rope sheave is equal to the elevator speed. With 2:1 roping the peripheral velocity of the rope sheave is twice the elevator speed.

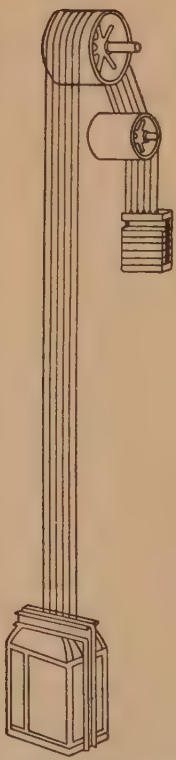
2:1 roping gives, usually, twice the capacity at half the speed. Thus an elevator rated 2,500 lbs. at 300 *f.p.m.* 1:1 roping could be roped 2:1 to carry 5,000 lbs. at 150 *f.p.m.* See fig. 6,753.

Gearless machines are 1:1 roped for 600 *f.p.m.* and above. For 500 or 450 *f.p.m.* they may be either 2:1 or 1:1. For 400 *f.p.m.* they are almost always 2:1 roped. The selection of one or the other depends on the speed and duty. 1:1 roping is sometimes called "direct hitch" or "straight hitch."

The object of using 2:1 roping instead of 1:1 roping in certain cases is to get the advantage of the lower first cost of the higher speed driving unit.

Thus, for example, an elevator rated 10,000 lbs. at 100 *f.p.m.* would have a lower first cost if it used a hoisting machine with a combination of gear ratio and sheave diameter suitable for 5,000 lbs. at 200 *f.p.m.* and roped 2:1 than if the hoisting machine were built with a gear ratio suitable for 100 *f.p.m.* and a load of 10,000 lbs. Such a machine could not be built economically with a single worm and gear.

A compound geared machine, that is a worm geared machine with an additional spur gear reduction, roped 1:1, could be used instead of the single geared machine roped 2:1, and there are certain cases, especially where the elevator speed does not exceed 100 *f. p.m.* where a compound geared arrangement is preferred.



FIGS. 6,759 and 6,760.—Roping for half wrap traction elevators. It will be noted how simple the roping is, there being only two cable bends (one as the cable leads onto the driving sheave and the other as it leaves) where the driving sheave diameter is one half the car width, although this is doubled when a deflecting sheave is necessary. However, for loads above approximately 15,000 lbs. a two to one roping is generally used. As the car width increases to a point where it is impracticable to further increase the diameter of the driving sheave, the amount of wrap possible on the driving sheave decreases. Therefore in the case of wide freight cars it is sometimes necessary to use the full wrap traction machine in order to get sufficient driving friction. The driving sheave bearing load is only one half that of the full wrap traction machine. One criticism of this type of elevator is the wearing of grooves in the sides of the V, thereby reducing the pinching action, although sheaves properly machined are still in good operating condition after eight or ten years of constant regular service. Moreover the rim in which the grooves are cut can readily be made removable for replacement.

As another example, take the case of 2,500 lbs. at 500 *f.p.m.* gearless.

In the motor speed table, page 4,121, if the traction sheave be 28 ins. the speed of the gearless motor is 136 *r.p.m.* 2:1 roping. If this machine were 1:1 roped, the speed of the gearless motor would have to be 68 *r.p.m.*

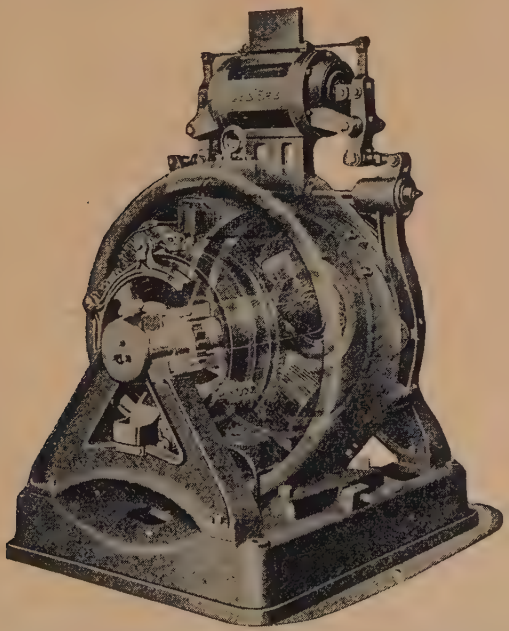


FIG. 6,761.—A. B. See gearless half wrap (V groove) traction elevator machine. It is built in sizes suitable for loads of 1,500 to 3,500 lbs. with one to one roping and speeds varying from 450 ft. per min. to the highest allowed under state and municipal regulations. The shaft does not revolve, being fastened to the pedestals. The duty of this shaft is solely to carry the load imposed upon it by the revolving parts of the machine and the weight of the moving parts in the hoistway. The brake consists of two independently operated shoes, provided with fabric linings. The pressure of the shoes on the brake drum is obtained by adjustable compression springs, and is released electro-magnetically on the application of current to the motor, in such a manner that should this current be interrupted from any cause the brake will be immediately applied and bring the car to rest. Means are provided to regulate the application of the brake so that it brings the car to a smooth stop. The various parts comprising the brake are all mounted directly on the field frame of the motor.

and such a motor would be much larger, heavier, and more costly than the 136 *r.p.m.* motor. However, the gain in cost of the higher speed motor is not all a net gain, as it is offset to a considerable extent by the added cost for sheaves, rope, etc., in 2:1 roping. Furthermore, owing to extra bends in the reverse direction, hoist ropes do not last as long in 2:1 roping as in 1:1 roping, and when they do wear out, cost more to replace.

Figs. 6,755 to 6,760 are roping diagrams showing all of the ropes. Figs. 6,759 and 6,760 show half wrap and figs. 6,755 to 6,758, full wrap roping for traction elevators.

Extension of Elevator Ropes

(According to American Steel & Wire Co.)

Length of rope in feet	Extension for cast steel rope in feet	Extension for plow steel in feet
500	0.833	1.000
1000	1.667	2.000
1500	2.500	3.000
2000	3.333	4.000
2500	4.167	5.000
3000	5.000	6.000
3500	5.833	7.000
4000	6.667	8.000
4500	7.500	9.000
5000	8.333	10.000

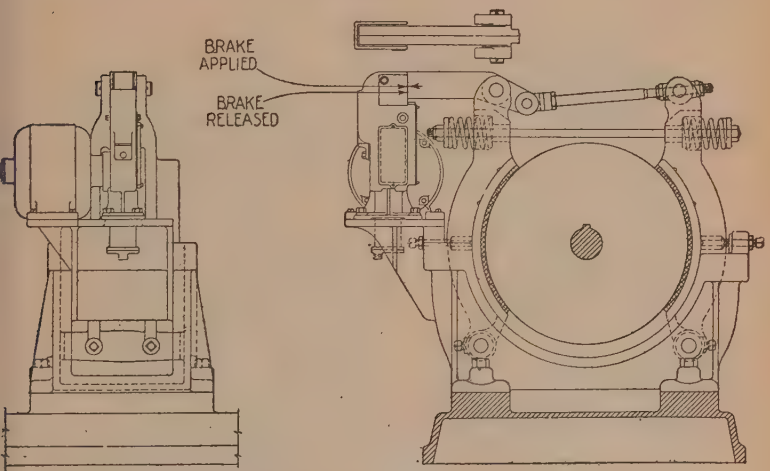
NOTE.—The foregoing extension acts in the case of sudden stopping or starting of a load attached to a wire rope to ease the stress a little. In the case of a short rope the elastic extension is small, but it increases proportionally to the increase in length of rope. This needs to be given due weight in any problem involving fast acceleration, jerks or shocks on a wire cable and the final safety factor should take into consideration these points.

NOTE.—***With all traction elevators*** there is the danger of slippage of the ropes on the driving drum, especially if the ropes become greasy. This slippage is most noticeable when the operator endeavors to stop in descending with a heavy load, with the result that on high speed cars when attempting to make a quick stop, the car sometimes slides past the landing even to the extent of one or more stories.

NOTE.—***The traction drive is not a positive drive.*** This is a safeguard for the reason that rope strains can never increase beyond a certain limit, well within the factor of safety of the ropes and fastenings. This means that the danger of the car or weight dropping, as a result of being pulled into the overhead work, and thus breaking ropes or fastenings, is eliminated

Every elevator machine requires a mechanical or friction brake to make the final stop and hold the load.

In some of the early forms of elevator machines, the brakes were mechanically released by hand ropes passing down beside the car, which also operated the control. The modern elevator brake is set by means of a spring and is released by a magnet. The brake wheel is mounted on the motor and worm shafts and usually serves also as a coupling between the two. The friction brake plays an important part in the successful operation of the elevator, since it must stop the car quickly and without producing an uncomfortable jar in the car



IGS. 6,762 to 6,764.—American torque type brake.

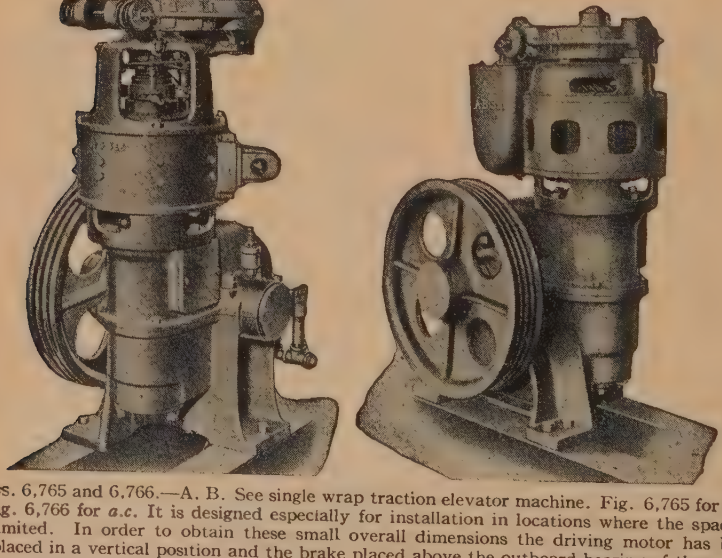
NOTE.—***In general*** gearless traction machines do not require commutating poles, as excellent commutation can be obtained without them. The most important requirements of uch a machine are good speed regulation both as a motor and as a dynamo, also compactness n design so that adjacent machines can be set above their hatchways.

NOTE.—***The gearless traction motor*** is smooth in operation and gives long life. It free from the lost motion or back lash which is inherent in the geared machine, and may e used in severe service where frequent starting and stopping and high rates of acceleration re essential. As the speed of elevators is extended upward to meet the needs of higher buildngs and more intensive elevator service, the gearless machine has the further advantage over ther types in that the increased speeds can be obtained by using higher speed motors, so hat the cost of the machine does not increase as rapidly as its output.

The accompanying illustrations show the brake as placed on the machine and figs. 6,768 to 6,770 construction details.

Gearing between Motor and Drum.—There are several forms of gear used to secure the velocity reduction between the motor and drum, necessary in most types of elevator. These may be classified as

1. Spur gear;
2. Herringbone gear;
3. Worm gear.



FIGS. 6,765 and 6,766.—A. B. See single wrap traction elevator machine. Fig. 6,765 for *d.c.* fig. 6,766 for *a.c.* It is designed especially for installation in locations where the space is limited. In order to obtain these small overall dimensions the driving motor has been placed in a vertical position and the brake placed above the outboard bearing of the motor instead of between the motor and the worm gear housing as in general practice.

Spur Gear Drive.—This well known method of transmitting power is extensively used in elevator practice. It is a "positive" drive, as distinguished from belt drive which is subject to

slippage. For moderate speed motors or machines in which the speed reduction between the motor and drum is not too great, spur gearing is well suited.

Obviously, where great speed reduction is required, as in an installation comprising a high speed motor and slow speed elevator it is not so well suited because of the large diameter of the drum gear required or the extra gears for double reduction necessary to obtain the necessary speed reduction. Clearly, such installations are best fitted with worm gear drive, as any speed reduction is easily obtained without the necessity of double reduction drive.

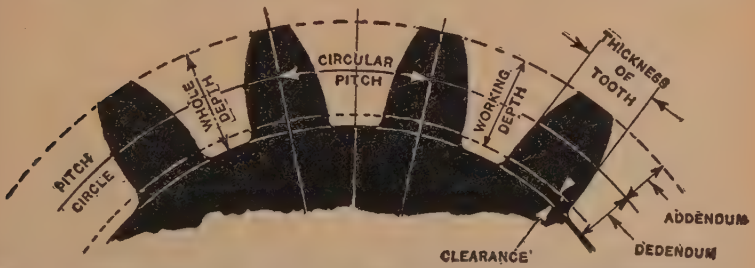
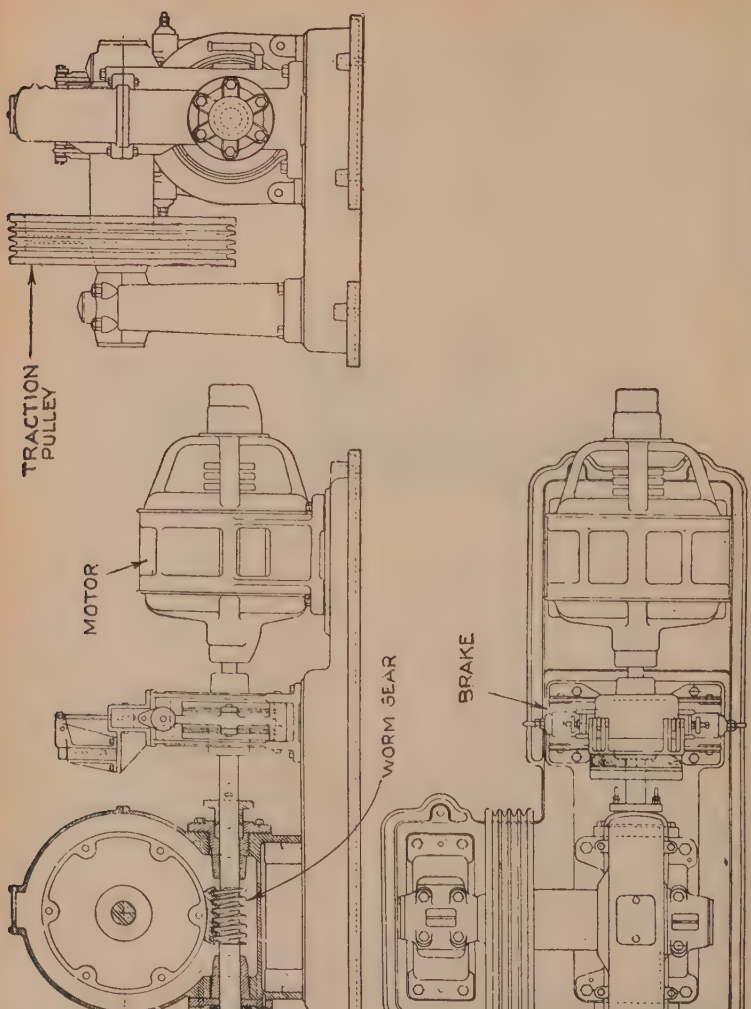


FIG. 6,767.—Gear tooth parts. ***Systems of spur gearing.*** Two systems of gear tooth are used for spur gears: the ***cycloidal*** and the ***involute.*** Of these, the involute system is the one more commonly used, especially for cut gearing. The standard involute gear tooth has a 14½ degree pressure angle, hence the rack meshing with gears cut according to this standard has straight sides inclined 14½ degrees from the vertical. ***Definition: Circular pitch*** is *the distance from center to center of two adjacent teeth along the pitch circle.* ***Diametrical pitch*** is *a number found by dividing the number of teeth by the pitch diameter;* that is, it gives *the number of teeth for each inch of pitch diameter.* ***Internal spur gears.*** The dimension of internal spur gears may be found by the same formulae as those for external spur gears, except for the modification made necessary by the fact that the center distance in internal gearing is equal to the *difference* between the two pitch radii, instead of the *sum.* In addition, the term inside diameter takes the place of the outside diameter of external spur gearing. This diameter, of course, is the diameter of the hole in the blank before the teeth are cut. ***In laying out*** the shape of teeth for internal gearing, interferences are almost sure to be met with. The points of internal gear teeth must, therefore, be relieved to avoid interference with the flanks of the meshing teeth. ***Interference occurs*** also when the pinion has too nearly the same number of teeth as the gear. In this case there is a tendency for the points of the pinion and the gear teeth to strike as they roll into and out of engagement. To avoid this interference, the teeth must be cut by specially made cutters or shaped on a gear shaping machine.

Herringbone Gear Drive.—This form of gear, sometimes called double helical tooth gear is a type in which right and left hand spiral teeth are both used.



Figs. 6,768 to 6,770.—Watson worm drive half wrap (V groove) traction elevator machine showing construction.

This gear has been tried extensively, giving very efficient operation, but it is understood that it is expensive to cut gears that insure quiet and smooth operation. This fact has limited its use.

Ques. Describe the Wuest system of herringbone gears.
Ans. The right and left hand sides of the gears are stepped half a space apart and do not meet at a common apex at the center of the face, as in the usual type of herringbone gear.

This stepped form wears more evenly under extreme loads than the ordinary type.

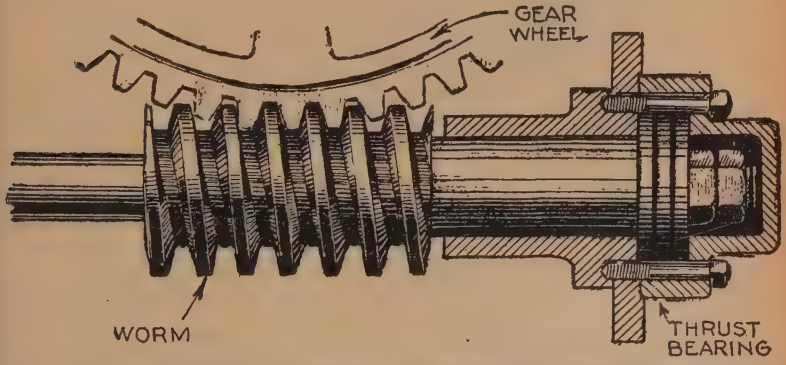
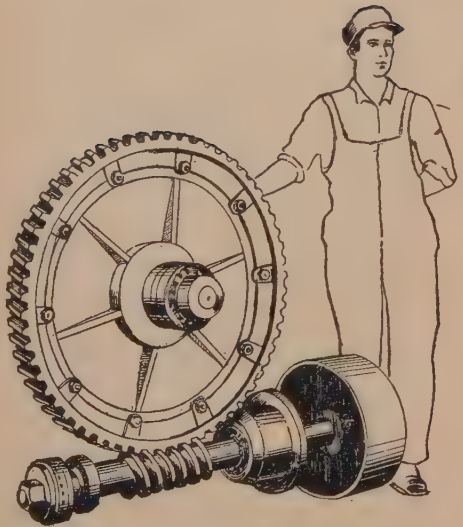


FIG. 6,771.—Single worm drive with ball bearing end thrust. The shaft on which the worm is cut is direct connected to the motor through a coupling with pulley shaped flange which is used as a braking surface. The single worm drive is suitable for relatively slow car speed and light loads. ***In construction*** worm drives are arranged to run in oil, accordingly the worm is placed below the gear wheel.

Worm Gear Drive.—This form of gear is very extensively used and is especially suited to slow speed elevators driven by high speed motors. A feature of worm gear drive is that it is self-locking because of the high velocity ratio, that is to say, no change in the loading of the car will produce movement.

In construction the gearing is enclosed in a cast iron box or casing which serves to protect the gears from dust and also to form a reservoir for oil used for lubrication. The worm is generally placed below the gear,



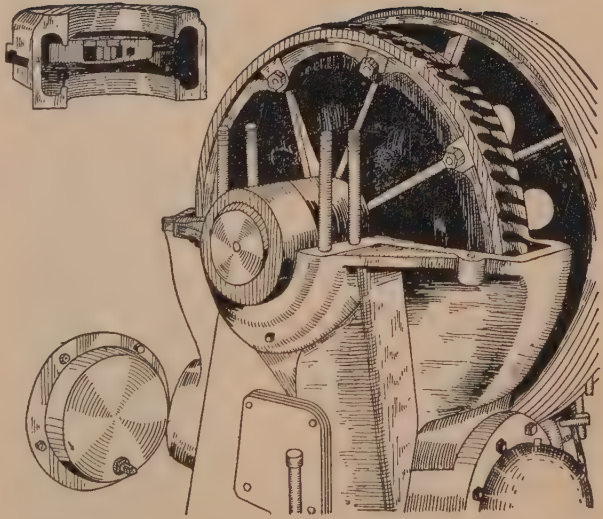


FIG. 6,772.—Haughton single worm gear.

FIG. 6,773.—Haughton adjustable bearings on one gear machine. This construction allows the gear to be adjusted under operating conditions to the correct position giving the proper contact and oil clearance.

in order that the worm may run in an oil bath. There are two kinds of gear:

1. Single gear;
2. Double or tandem gear.

An undesirable feature of the single worm drive is *end thrust.*

Clearly with a heavy load there is considerable pressure endwise on the threads of the worm which is accompanied by friction (loss of power) and wear, moreover a special form of bearing called a thrust bearing is required to take this end thrust.

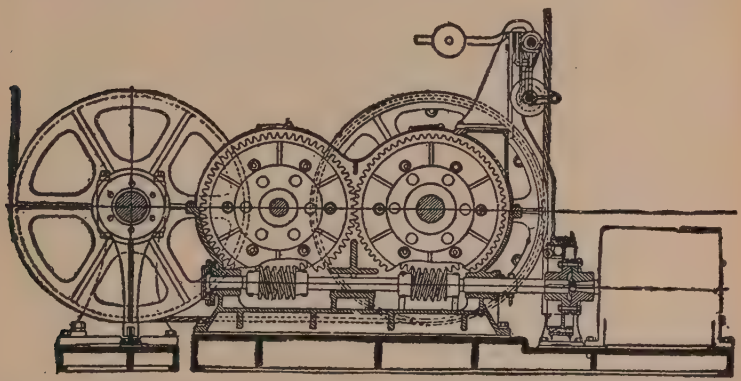


FIG. 6,774.—Tandem worm drive machine with independent concave face gears meshing with the worm as shown by the portions of the larger gears cut away above the worms. As shown, there are four gear wheels bolted together in pairs, the two larger ones meshing with each other, and the two smaller ones with the worms.

Ques. Describe some forms of end thrust bearing.

Ans. For light service, discs of bronze and steel suffice to take the thrust; for medium duty ball bearings should be used; and for heavy duty, roller bearings.

The details of construction are shown in the accompanying cuts.

Ques. What is the object of a double or tandem worm gear?

Ans. To eliminate the end thrust.

Ques. Describe a double worm gear.

Ans. Two worms, usually forged solid to one shaft, are employed; one, a right hand worm, and the other left hand. These worms mesh with two gears of equal size as in fig. 6,774.

Double Reduction Worm and Internal Gear Drive.—For very slow heavy duty freight elevators, operated by high speed motors, the excessive speed reduction necessary is best obtained by double reduction drive employing a combination of worm and internal spur gear.

TEST QUESTIONS

1. *Name two general classes of elevator machines.*
2. *What are the essential parts of an elevator machine?*
3. *What is the difference between a drum and a traction pulley?*
4. *Describe the operation of a drum machine.*
5. *How is the weight of the car balanced?*
6. *Describe different methods of roping the counter-weight.*
7. *What names are given to the two types of machine with respect to location?*
8. *Which type of machine gives direct transmission?*
9. *What is the advantage of installing the drum machine overhead?*

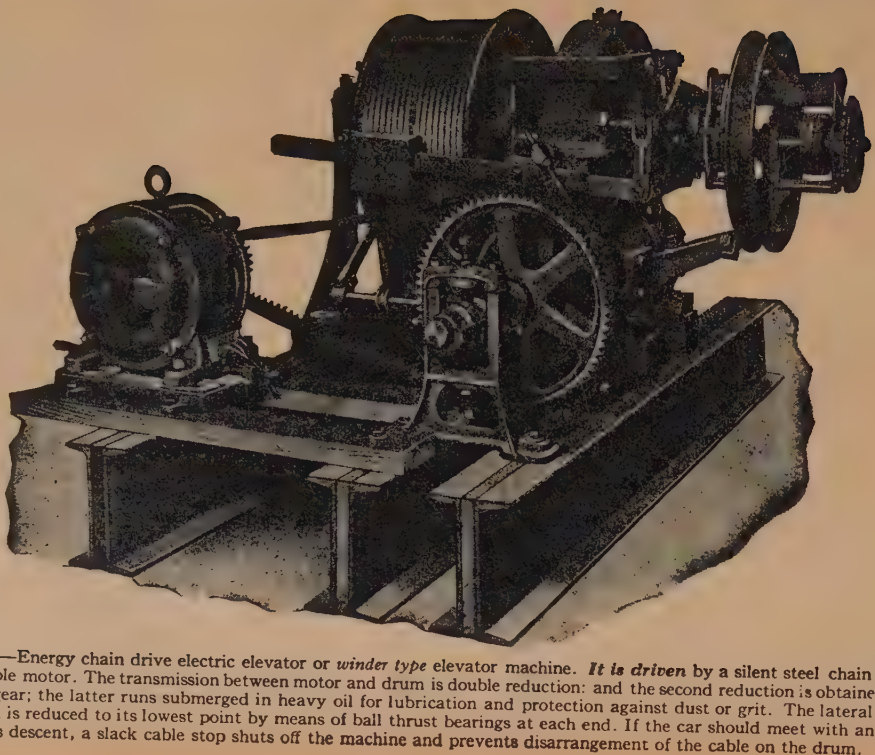


FIG. 6,775.—Energy chain drive electric elevator or *winder type* elevator machine. ***It is driven*** by a silent steel chain belt from a reversible motor. The transmission between motor and drum is double reduction: and the second reduction is obtained through a worm gear; the latter runs submerged in heavy oil for lubrication and protection against dust or grit. The lateral friction of the worm is reduced to its lowest point by means of ball thrust bearings at each end. If the car should meet with any obstruction in its descent, a slack cable stop shuts off the machine and prevents disarrangement of the cable on the drum.

10. *Why is the drum machine not the prevailing type?*
11. *Describe at length a traction elevator installation.*
12. *What is the difference between half wrap and full wrap roping?*
13. *What other names are sometimes given to half wrap and full wrap?*
14. *What determines whether a V groove or a U groove be used?*
15. *Describe one to one or direct drive and two to one reduction roping.*
16. *What type drive is used for multi-reduction transmission?*
17. *For what speeds are the various types of roping used?*
18. *What is the principal object of using a two to one roping instead of one to one?*
19. *Mention an inherent fault of traction elevators.*
20. *Describe the various forms of gearing between motor and drum.*
21. *Name an objection to herringbone gear.*
22. *Describe the construction of worm gearing.*
23. *Name some forms of end thrust bearing.*

CHAPTER 155

Elevator Motors

No matter how good an elevator controller may be, it is obvious that without the right type of motor the elevator service is bound to be unsatisfactory.

A few suggestions regarding the selection of motors for elevator work may be helpful.

In order to insure rapid acceleration and retardation, the inertia of moving parts must be kept as low as possible. For this reason motors for elevator service are designed with armatures of comparatively small diameter. Slow speed motors are preferable.

Generally speaking, the motor speed should not exceed 900 revolutions per minute.

Motor speed, of course, is not so important on slow speed as on high speed elevators.

Power Calculations.—In order to determine the size of motor required for a given installation three factors must be considered:

1. Load or net weight to be hoisted;
2. Speed of the car;
3. Efficiency.

NOTE.—***For full information*** on principles, construction, operation and maintenance of *a.c.* and *d.c.* motors, see Volumes 2 and 5 of this Series.

With regard to the load or weight to be hoisted, since it is customary to counterbalance the weight of the car and part of the load this must be taken into account, that is, only the unbalanced load is considered.

The efficiency is the "overall" efficiency; it includes the various frictional and electrical losses. Accordingly when this is known and inserted in the formula the horse power obtained is the horse power input to the motor.

The horse power required may be obtained by inserting the given values in the following formula:

$$\text{horse power} = \frac{L \times S}{E \times 33{,}000}$$

in which

L = unbalanced load in pounds;

S = speed of elevator in feet per minute;

E = efficiency of the system generally taken at 50%.

Example—What size motor will be required for an elevator having an unbalanced load of 2,000 lbs. 400 ft. per minute speed and overall efficiency of 50%?

$$\text{horse power} = \frac{2{,}000 \times 400}{.5 \times 33{,}000} = 48$$

The horse power required for a given installation may be easily and quickly obtained from the chart shown in fig. 6,776. In the chart the efficiency of the elevator is assumed to be 50%. For any other efficiency divide the horse power obtained from the chart by two and then divide this result by the known efficiency.

Example—A certain elevator has a capacity of 3,000 lbs.; car speed 200 ft. per minute and with 1,000 lbs. over counter-weight; 65% overall efficiency. Determine from chart the size of motor required.

The net load to be lifted will be 2,000 lbs. The diagonal line for 2,000 lbs. cuts the 200 ft. per minute vertical line at the horizontal line which corresponds to about 25 *h.p.* This will be the size of the motor required if the overall efficiency of the elevator be 50%. If 65% be the known efficiency, the required horse power will be less.

$$\text{horse power} = \frac{25}{2} \times \frac{1}{.65} = 19.2, \text{ say } 20.$$

Starting Torque Requirements—While the formula and chart just given provide a reasonably accurate method of obtaining the horse power rating of the motor for a particular installation, it is desirable, especially with *a.c.* motors, to consider each motor from the standpoint of its starting torque as well as its horse

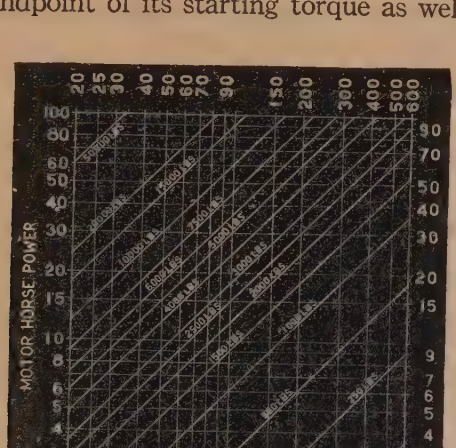


FIG. 6,776.—Elevator motor horse power diagram. Three factors determine the horse power of the motor that should be used, namely, the weight to be hoisted, the speed of travel and the efficiency of the elevator. ***In the diagram,*** the efficiency of the elevator is assumed to be 50 per cent. To determine the proper size motor to use in any case follow the diagonal line corresponding to the unbalanced load up to the point where it crosses the vertical line corresponding to the speed desired. The horizontal line at this point will indicate the horse power of motor required.

power rating. The chart cannot always be depended upon to insure sufficient starting torque.

It is a well known fact that an elevator requires greater starting torque than is necessary to keep the same elevator running at its rated speed and load.

With full rated load on an elevator the effort or torque required to start this load will be, as a rule, from two to two and one half times as great as the torque required at full load. This is due mainly to static friction, and the exact amount varies with the overall efficiency of the installation. A motor, therefore, to be suitable for elevator work, should be capable of developing from two and one-quarter to three times as much starting torque as is represented by its horse power rating.

Motor builders do not as yet design all their motors with the same ratio of starting torque to full load torque.

This is particularly true in the case of high torque squirrel cage motors, and also to some extent in the case of wound rotor slip ring motors.

The "inrush" current limitations which are placed on elevator motors by many central stations also cut down the amount of starting torque which could otherwise be obtained.

After any gear driven machine starts there is usually a decided increase in efficiency of the gearing owing to the oil film which rotation effects between the gears. Also on all types of elevator machines the efficiency increases after starting due to the oil film which rotation automatically places between the bearings. Therefore, immediately after starting there is an excess of torque which becomes available for acceleration. The amount of this torque depends first, upon the excess motor torque that is provided over and above that actually required to start the machine in motion, and second, upon the excess in elevator starting efficiency over and above an assumed 20 per cent.

In the following formula for the determination of torque required to start an elevator, the starting efficiency has been assumed at 20 per cent as outlined below.

NOTE.—The difference in treating the matter of torque and horse power by different manufacturers of motors has proved confusing. It is therefore of interest to know that the Electric Power Club has taken the subject in hand and is now working out standard ratings which it is hoped all motor manufacturers will adopt. If a specific installation have an overall running efficiency of 50 per cent and it requires two and a half times full load running torque of the motor in order to start the maximum rated load in the hoisting direction. the starting efficiency will be only 20 per cent.

If this efficiency in any case be lower, the elevator will not start with the torque as derived by the formula.

If the efficiency be greater and allowance be not made in the formula, the derived torque may be so great that the start will be abrupt unless some control arrangement, external to the motor, be included to reduce the initial torque.

$$T = \frac{5{,}252 \times L \times S \times 2\frac{1}{2}}{33{,}000 \times .5 \times r.p.m.}$$

$$T = \frac{.8 \times L \times S}{r.p.m.}$$

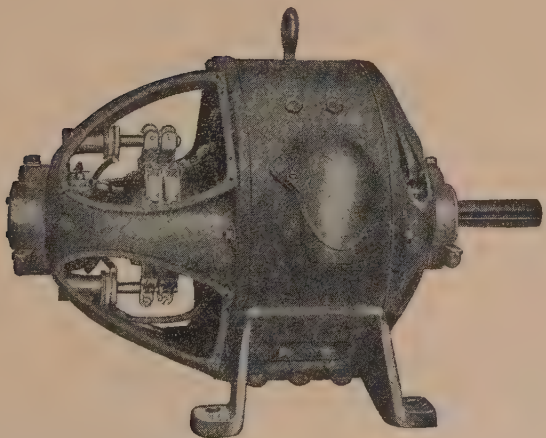


FIG. 6,777.—Exterior view of Westinghouse *d.c.* elevator motor. To secure good commutation and quiet running interpoles are used and the armature provided with a large number of slots; also the main poles are beveled.

in which

T = Torque in pounds at one ft. radius on the motor shaft.

L = Net load in lbs.

S = Full speed of elevator in ft. per min.

r.p.m. = Full load speed of motor selected.

Direct Current Motors—The type of direct current motor

which is best suited to elevator service depends to a considerable extent on the type of service, that is, the speed and frequency of stops.

The elevator motor must not only raise and lower the load, but one of its principal duties is to accelerate and decelerate the car rapidly. This must be accomplished smoothly without jars or jerks which might cause discomfort to the passengers.

For freight service compound wound motors are recommended.

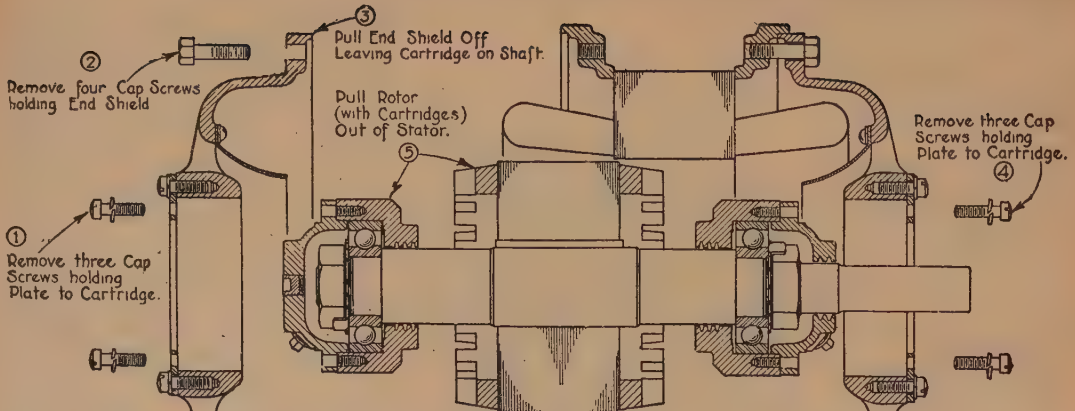
The series winding provides a high starting torque, an essential factor for heavy duty work. With full load current the compound winding should

FIG. 6,778.—General Electric *d.c.* ball bearing elevator motor with cartridge type housing. The construction of the housing for oil lubrication differs somewhat from that employed for grease lubrication. The latter type is here shown.

have from 10 to 15 per cent of the ampere turns of the shunt field. By cutting out the series winding after starting, the motor becomes a constant speed machine, the most desirable type for the varying loads encountered in elevator service.

For passenger service, either compound wound or shunt wound motors give satisfactory results.

For speeds above 200 ft. per minute, motors of the variable speed type should be used. Between 200 and 350 feet per minute, a speed range by shunt field control of two to one is common. Above 350 feet per minute greater speed ranges are necessary to secure satisfactory operation. Many



FIGS. 6,779 to 6,785.—Details of construction of General Electric cartridge type unit elevator motors for *a.c.* or *d.c.*

installations are now being made with three to one motors for car speeds of between 500 and 600 feet per minute.

When a dynamic braking controller is used the motor should be capable of commutating, without difficulty, dynamic braking currents whose values approximate 175 percent of the full load current of the motor.

Controllers which provide the dynamic braking feature also require a motor whose shunt field winding is capable of standing one-half the line voltage continuously without overheating with the motor armature at rest.

Most direct current motors, whether shunt or compound wound have suitable commutating pole windings so as to insure sparkless commutation in both directions of rotation.

The commutation should be such that with heavy momentary overloads at starting and during dynamic braking, the commutator will remain in satisfactory operating condition without need for frequent attention.

The adjustable-speed, shunt-wound motor, usually having a speed range of two to one or more by shunt field control, provides ample starting torque without a compound winding. For high speed installations, if this type of

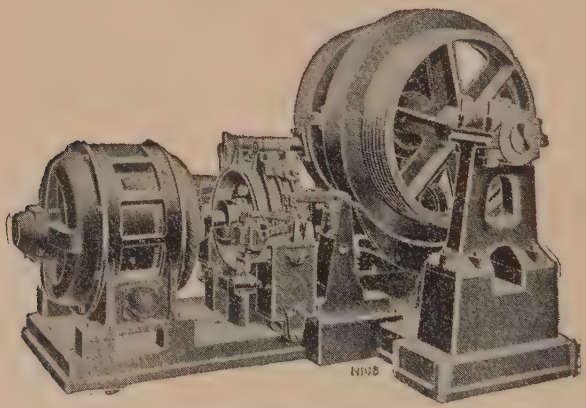


FIG. 6,786.—General Electric multi-speed induction motor on a V-grooved geared traction elevator machine. This type of motor can be used for elevators running as fast as 350 *f.p.m.* provided the car is traveling slow enough when operating on slow speed connections (about one half full load speed) to give the required accuracy of landing, which depends on the character of service. For department store service, demanding stops at each floor, the highest elevator speed for which this type of motor is recommended is 275 *f.p.m.* These motors are wound for three phase circuits only. When two phase power is available use Scott connected or auto transformers depending on the power supply. The field has but one winding. The two synchronous speeds are obtained by polar regrouping. This regrouping of poles is accomplished by contactors on the control board. The armature is of the high resistance, indestructible squirrel cage type, and gives high starting torque. The low speed connection is used in starting and stopping. The high speed connection is used for high speed running. The motor is furnished for direct connection without base or pulley. These motors operate very quietly and can be used in such places as clubs, hotels, private residences, hospitals, etc.

motor be used, the elevator can be run at full field speed practically as efficiently as at high speed. In transferring from high to full field speed the motor acts as a dynamo and returns current to the line. The amount of this

returned current has been found from actual test of a three to one motor to equal 10 per cent of the total power consumption on an elevator making 150 stops per car mile. For slowing down from full field to "drag" speed, *series parallel* resistor connections are used, but the horse power is only a fraction of that at high speed, so that a saving of power at drag speed is realized over power used in slowing down a single speed motor. Should anything happen to the armature shunt contactor or to the armature shunt resistor circuit the operator can always slow down to full field speed and make a safe stop without dynamic braking.

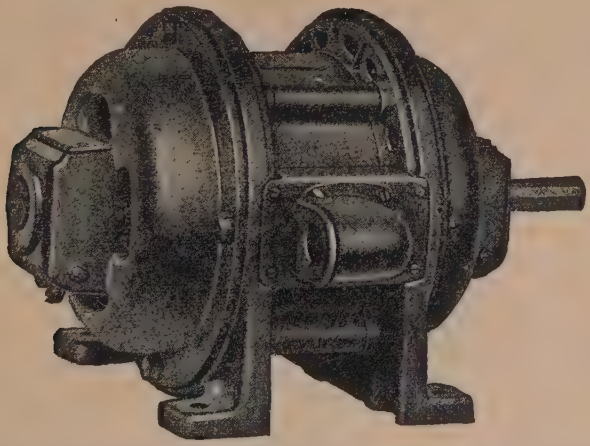


FIG. 6,787.—General electric constant speed induction motor. Designed for continuous duty cycle at rated horse power 15 seconds on, 45 seconds off, without exceeding 50 deg. Cen. rise. They will operate at rated horse power 30 minutes without exceeding 50 deg. Cen rise, if started cold. The temperature on the armature may exceed 55 deg. Cen. rise. Motor heating on ordinary counter-weighted elevators is not as important as the starting torque because full rated horse power is required only when the elevator is hoisting full load or lowering light load, whereas a much smaller horse power is required when the elevator is hoisting a light load or lowering a heavy load; but the motor is liable to damage if an attempt be made to lift a greater load than it can start. This type motor attains full speed in less than one half of a second under usual conditions of full load; and during this time, the average starting current is less than twice full load current.

Alternating Current Motors.—Because of improvements in motor design and through the use of properly designed controllers, many of the limitations which were formerly attributed to the use of alternating current motors in elevator service have

been successfully overcome. With the usual single speed motor, it is still impossible to employ dynamic braking or anything equivalent to it. The elevator must be slowed down and stopped by the mechanical brake alone.

This is a difficult problem because the mechanical brake is capable of absorbing this energy only in direct proportion to the velocity, while a dynamic brake will dissipate this energy in proportion to the square of the velocity. The dynamic brake, unavailable with alternating current, is an important adjunct in assisting the mechanical brake for quick, smooth stopping of the elevator.

There are two general types of *a.c.* motors suitable for elevator service:

FIG. 6,788.—Westinghouse single speed, slip ring elevator motor. Designed for freight and passenger service where the elevator speeds are not too high to permit making satisfactory stops with a mechanical brake. Largely used for operating heavy elevators requiring motors larger than 25 horse power.

1. Squirrel cage motor;
2. Slip ring motor.

The squirrel cage motor is used extensively up to about 20 *h.p.* because of its simplicity and because it requires only a relatively simple form of controller as it is generally thrown across the line with no starting resistor.

When the installation is such as to require a smooth start, a resistor or reactance is placed in the motor primary circuit and gradually cut out after starting. The last method of starting has been applied to motors as large as 50 *h.p.* with success. However, it has one disadvantage in that its speed regulation is poorer than that of a slip ring motor. While this is of little moment for the lower speed elevators, it may not be satisfactory on the higher speed cars. It is of interest to note that this regulation is not as bad as that of a hydraulic elevator.

In actual service the power consumption of the squirrel cage motor is slightly higher than that of the slip ring machine, but due to the lack of slip rings and fewer controller parts it is somewhat more reliable.

The slip ring motor for the same rating is more expensive and has a somewhat lower power factor than the squirrel cage motor.

The slip ring motor is a standard product and has been used practically as long as electric elevators have had *a.c.* drive.

It has a higher full speed running efficiency because the resistor in the rotor circuit is cut out by the controller after the motor starts. Its disadvantages have already been outlined.

A.c. motors of the two speed type are now available and are being used successfully on elevators whose car speeds are as high as 400 feet per minute.

The customary speed range is three to one, the motor being designed with two separate primary windings. Under normal conditions the motor is accelerated on the high speed winding. The slow speed winding is used for inching and in slowing down to make a landing. For this latter use, the slow speed winding acts as a sort of dynamic brake and insures smoother retardation and a more accurate stop than would be possible with the customary *a.c.* motor.

By using a suitable controller and an automatic governor it is possible to secure automatic dynamic braking on this type of motor when the car switch is thrown from the high speed to the off position without stopping at the slow down position. The governor automatically provides dynamic braking in the off position of the car switch in case the motor is running above synchronous speed of the slow speed winding. The use of this governor eliminates the possibility of an extreme slide of the car.

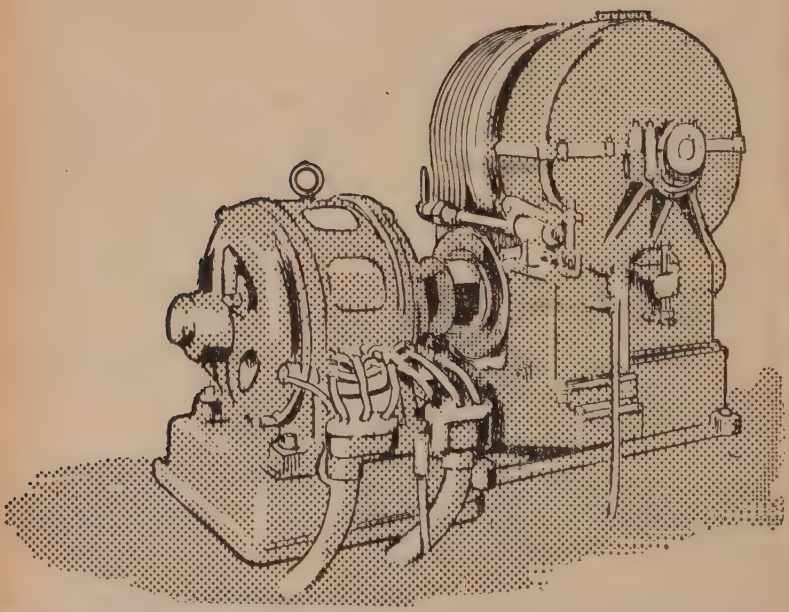


FIG. 6,789.—Westinghouse two speed induction motor driving elevator machine. ***In operation*** the controller is so arranged that the motor starts on the slow speed winding with resistors in series with this winding. The resistance is automatically cut out of the circuit as the motor accelerates. After the motor is operating on full voltage low speed, it is switched over to the high speed winding with resistors again in series with the motor. The resistors are in turn switched out of the circuit, leaving the motor running at its high speed, on full voltage. This sequence of operation takes place automatically when the operator moves the car switch handle from the off position to the full speed position. For moving the car short distances, the car switch handle is moved to the intermediate position and the motor operates at its low speed. When the car is stopped, the equipment follows a similar cycle, although reversed. The operator moves the car switch handle from the full speed position, directly to the off position. The motor is switched automatically to the low speed winding and it operates at this speed for a short period of time before being stopped. This always gives the desired braking action on stopping independently of any action of the operator. Resistance steps are also used on stopping, to give smooth stops. In addition, with equipments for car speeds above 250 feet per minute reactor coils are used in the line circuit to smooth out sudden changes of current values, giving extremely smooth changes in car speeds.

As in *d.c.* service all *a.c.* elevator motors should be designed especially for elevator work.

The starting torque should be at least 225% of the rated full load torque. Motors having more than approximately 15% variation in speed from no load to full load are not recommended for elevator service.

Polyphase motors of both the slip ring and squirrel cage types give satisfactory results.

A secondary resistor is used with slip ring induction motors. Primary resistors are used with squirrel cage motors to secure smooth acceleration. For slow speed service the squirrel cage motor is often thrown directly across the line. Motors of this type when connected directly to the line should not take more than two and one half to three times normal full load current.

Single phase motors of the self starting *repulsion induction* type may also be used for elevator service.

Single phase motors of the standard split phase or standard repulsion induction type are not suitable for elevator service because of the uncertainty as to whether the motor will reverse when the connections are reversed quickly.

Starting Current Inrush.—The National Electric Light Association has adopted certain rules which limit the starting current inrush. The two tables which follow show the maximum current inrush for the various sizes of motors.

NOTE.—***Some manufacturers*** in order to get positive speed control with *a.c.* are using two motors of different rated speeds both of which are direct connected to the elevator machine. This scheme permits the use of a squirrel cage motor for the low speed member and a slip ring motor for the high speed member. With this arrangement it is possible to obtain the advantages of lower slip and higher operating efficiency which are characteristic of the slip ring motor. Another point in favor of the two motor arrangement is that the windings are in the usual form with which all repairmen are familiar and therefore the chances are that quicker repairs can be made. Also equipments have been built consisting of two distinct motors, both in one motor frame. The two speed *a.c.* motor is being successfully used with car speeds as high as 350 ft. per min. Further development will undoubtedly increase this maximum.

These tables show the maximum permissible starting current values for a single motor installed and connected to its load. Many power companies have already adopted these rules as being reasonable and well within the possibilities of good elevator practice. All power companies should be urged to adopt them, in order to have a universal standard.

Some power companies place practically no limitations on starting currents, while others are more rigid in their requirements than the rules of the N.E.L.A.

Alternating Current Motors

Polyphase—Sixty Cycles

h.p. of motor.	Line voltage.	*Line amperes per phase per *h.p.*	
		Two phase.	Three phase.
1	220	17.3	20
1–2	220	15.2	17.5
3–5	220	11.2	13
	440	5.6	6.5
	550	4.5	5.2
6–30	220	8	9
	440	4	4.5
	550	3.2	3.6
	2,200	1	1
Above 30	220	5.2	6
	440	2.6	3
	550	2.1	2.4
	2,200	0.5	0.6

*Current values are those indicated by a suitable well damped ammeter in the motor circuit on the line side of the starting device, and are 75% of the permissible locked rotor values.

Direct Current Motors

Shunt and Compound Wound

Size of motor	Volts	*Amperes per *h.p.*
3 *h.p.* and below	230 550	12 5
Above 3 *h.p.*	230 550	9 4

*Current values are those indicated by a suitable well damped ammeter on the line side of the starting resistor.

Motor Speeds

	Load	Speed *f.p.m.*	Sheave diam. ins.	Sheave speed *r.p.m.*	Motor speed *r.p.m.*	Ratio of worm and gear
Single worm geared V groove single wrap traction elevator 1:1 roped	2,000	300	30	38	1,030	27:1
Gearless U groove full wrap traction elevator 2:1 roped	2,500	500	28	136	136	None
Gearless U groove full wrap traction elevator 1:1 roped	3,000	700	36	75	75	None

In such cases an unnecessary hardship is placed on the elevator manufacturer and on the owner of the building in which the elevator is installed. As a rule, such stringent regulations can only be met by using an oversized motor.

If the motor be of the squirrel cage, high torque type, the addition of a primary resistor on starting will be helpful. This resistor can be short circuited while running.

Motor Speeds.—The table on page 4,121 shows values typical of those in common use of a few types of elevators.

This table shows very clearly the distinction between geared and gearless machines. In the geared machine the required slow speed for the traction sheave is obtained by a gear reduction. In the gearless machine the required slow speed is obtained by using a large frame direct current motor with a winding which produces full power at a very low *r.p.m.*

TEST QUESTIONS

1. *What is the maximum motor speed which should be used?*
2. *Name three factors which must be considered in determining the size of motor required for a given installation.*
3. *Define overall efficiency.*
4. *Give formula for horse power of motor.*

NOTE.—For additional practical information on motors of all types see other volumes of this series.

5. *How may the horse power required be easily determined?*
6. *What are the starting torque requirements?*
7. *Is greater torque required while starting or while running?*
8. *Name the important requirement for a motor to be suitable for elevator service.*
9. *Give formula for the determination of starting torque.*
10. *Upon what does the type of* d.c. *motor best suited to elevator service depend?*
11. *For what service are compound wound motors desirable?*
12. *What two types of* d.c. *motor are satisfactory for passenger service?*
13. *Are* a.c. *motors desirable for elevator service?*
14. *Name two types of* a.c. *motor in general use.*
15. *What is the advantage of the squirrel cage motor?*
16. *Describe the conditions for which the various types of* a.c. *motor are suitable.*
17. *Are polyphase motors used?*
18. *What type of single phase motor is used?*
19. *Are split phase motors suitable for elevator service?*
20. *Why should the starting current inrush be considered?*
21. *Do all power companies place limitations on starting current?*

22. *How can stringent regulations in regard to starting current be met?*

23. *What are the motor speeds used for various types of motor?*

CHAPTER 156

Elevator Control Systems

The author is indebted to Mr. C. F. Scott, E.E. of the Gurney Elevator Co. for able assistance in the preparation of this chapter

In any elevator installation, the type of control system used governs the selection of the motor. Accordingly, further explanation relating to motors will be given in this chapter.

The great variety of control systems may be broadly divided into two general groups, classified according to the basic principle of operation employed, and known as

1. Rheostatic control.
2. Variable voltage control.

Rheostatic control.—This method includes *practically everything not included in variable voltage control.* It includes control of single speed motors and motors with two or more speeds.

With rheostatic control the motor which is connected to the worm shaft of the elevator is direct current if the supply circuit be direct, and alternating current if the supply circuit be alternating. In variable voltage control, the motor on the elevator machine is always direct current.

The various types of rheostatic control, according to speed and motors used, are:

1. Single speed, direct current.
2. Single speed, alternating current.

a. High resistance rotor squirrel cage induction motor.
b. Slip ring or wound rotor induction motor.
c. Single phase motor.

Single speed motors are seldom used for elevators with a speed higher than 200 *f.p.m.* and frequently not above 100 *f.p.m.*

High resistance squirrel cage induction motors are used much more than slip ring motors.

Single phase motors are used in elevators only where two or three phase is not available, and usually only where the power requirement is very small, 5 *h.p.* or less.

3. Multi-speed, direct current.

   a. With small range field control on the motor and with armature by pass resistance.

   b. With wide range field control on the motor and with or without armature by pass resistance.

4. Two speed, alternating current.

   a. Single rotor squirrel cage induction motor with two superimposed stator windings.

   b. Single rotor squirrel cage induction motor with single stator winding arranged for grouping in two different polar combinations, one giving twice the speed of the motor.

   c. Double rotor induction motor, with one squirrel cage and one slip ring rotor, and two separate stator windings.

The typical *d.c.* elevator motor for speeds 200 to 400 *f.p.m.* is compound wound, the series field being frequently shorted out at full speed; starts with a resistance by-passed around the armature, this resistance being increased in value, then shorted out as the elevator comes up to speed and finally inserts resistance into the field to reach top speed.

The motor in this case has a range of speed by field of about 700 to 850 *r.p.m.* Dynamic braking is applied to retard the elevator before the mechanical brake is applied.

The *d.c.* elevator motor with wide range field control involves the use of a large and more costly motor for the same duty, as compared with the motor described in the preceding paragraphs but the control is simpler, the energy consumption less and the regulation is better, making stops easier.

An example of this type is the Gurney motor and control for a duty such as 2,500 lbs. 450 *f.p.m.* The motor is shunt wound, with a speed range by field of 300 to 900 *r.p.m.* No armature by-pass is used in starting, but dynamic braking is used in stopping. This system shown in fig. 6,791, has the lowest *kw. hr.* consumption per car mile that it is possible to attain.

The single rotor squirrel cage induction motor with two super-imposed windings is the standard type for 2 speed *a.c.* rheostatic control.

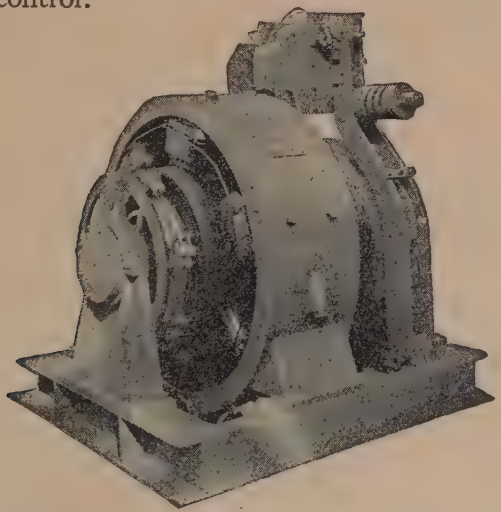


FIG. 6,790.—General Electric all steel roller bearing gearless elevator motor. In a gearless machine the traction sheave is mounted on the armature shaft or spider and turns at the same speed as the armature, which must develop full power at a low speed of revolution. For example, if the sheave be 36" diameter and the elevator speed 700 *f.p.m.* the motor armature must run at approximately 75 *r.p.m.*

It is used for speeds of from 200 to 400 *f.p.m.* for passenger service and for speeds of 100 to 250 *f.p.m.* for freight service. The ratio of the high speed to the low speed may be 3:1, 4:1, or 6:1. Occasionally odd ratios are used, as, 16:6. On 60 cycles these ratios give speeds such as 1,200/400, 900/300, 1,200/300, 900/225, 900/150, 1,200/450.

The motor is started usually on the high speed winding, with resistance in series which is cut out in one or more steps in the first second or so of

acceleration. Smooth performance is the result of the inherent characteristics of the motor and depends also on proper adjustment of the resistance in the controller.

In retarding the car, the high speed winding is disconnected and the low speed winding connected in circuit. During the few seconds required for the car to slow down from high speed to low speed, the elevator, owing to its momentum, actually drives the motor, which then for the time being becomes a dynamo, and exerts a powerful counter-torque or braking action.

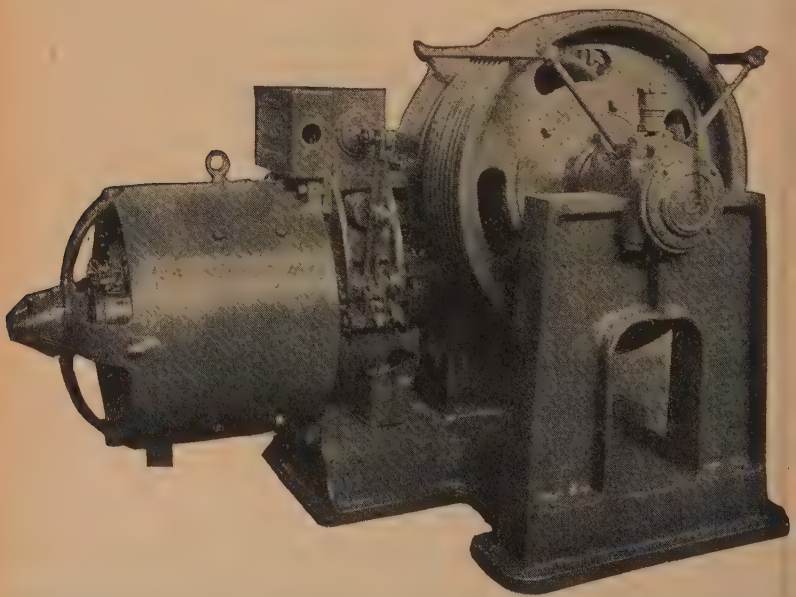


FIG. 6,791.—Gurney worm geared elevator machine with Gurney *d.c.* adjustable speed wide range field control motor. This type of motor is used for elevator speeds of from 200 to 450 *r.p.m.* with rheostatic control, where the source of current supply is *d.c.*

As the dynamo or braking action of an induction motor can only occur at speeds above synchronous speeds, the regenerative braking in an elevator with a two speed motor can be maintained only down to the point where the elevator speed corresponds to the rated speed of the low speed winding. From this point down to final stop the retarding force is derived from the mechanical brake.

FIG. 6.792.—Gurney *d.c.* rheostatic controller for the *d.c.* motor illustrated in fig. 6.791.

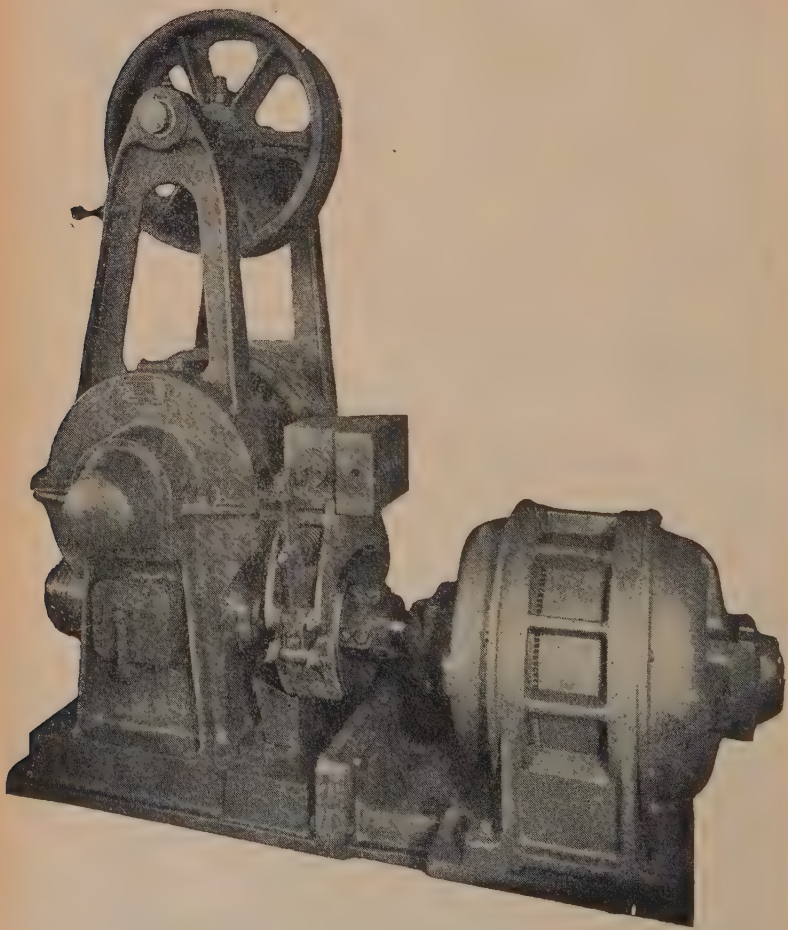


FIG. 6,793.—Gurney worm geared elevator machine with General Electric *a.c.* 2 speed motor for rheostatic control. This machine has a *d.c.* solenoid brake and the control magnets are also operated on *d.c.* this current being obtained from a small motor dynamo set. This machine is for basement mounting.

The control is provided with a timing device, so that even if the switch be centered or returned to neutral position from full speed, the low speed winding will be held in long enough to bring the elevator down to the proper speed for the mechanical brake to be applied.

On retarding, resistances are inserted in the low speed winding. These resistances are shorted out automatically in a number of steps during the first few moments of retardation. The smoothness of retardation is dependent to a considerable extent on the proper adjustment of these resistances.

Because of the greater simplicity, more compact construction, quieter operation and greater adaptability to gradual application and release, a direct current brake solenoid is to be preferred to an alternating current brake.

For this reason it is becoming common practice to equip the better grade *a.c.* rheostatic elevators with a direct current circuit for the brake and the control magnets. This *d.c.* is usually obtained from a small motor generator set that is automatically controlled.

The second type of 2 speed motor has a single stator winding, usually with 6 or 8 poles in 60 cycles, with leads brought out so the winding can be regrouped to give 12 or 16 poles.

This gives speeds of 1,200/600 or 900/450. This type of induction motor has a relatively wide application in industrial fields, and formerly was extensively used in elevator service, but now is largely superseded by the first type just described.

The third type of 2 speed motor usually has a squirrel cage rotor and a slip ring rotor on the same shaft.

The slip ring element is usually the high speed part, 1,200 or 900 *r.p.m.* and the squirrel cage element the low speed part, 400 or 300 *r.p.m.* This type of motor has higher running efficiency and closer speed regulation in the high speed winding when running at full speed, but its starting efficiency is low, and its great size and weight, combined with high power consumption when there are many stops, have caused it to be largely superseded by the first type.

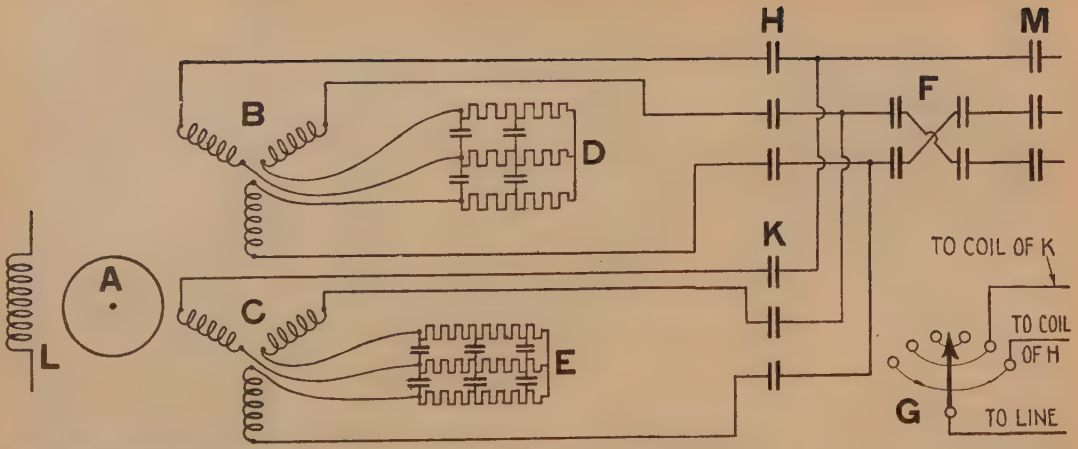


FIG. 6,794.—Elementary diagram of basic circuits for *a.c.* rheostatic two speed control.

Principles of Rheostatic Control.—To illustrate this method of control, a schematic diagram of the basic circuits for an *a.c.* low speed installation is shown in fig. 6,794.

In the figure, A, is the squirrel cage armature of the motor; B, upper or high speed field winding, grouped say for 6 poles; C, lower or low speed field winding, grouped say for 18 poles; D, starting resistance for winding B; E, buffer or retarding resistance for winding C. Sometimes D, and E, are combined by putting B and C, in series instead of in parallel as shown.

F, is a reversing device, usually two double pole magnetic switches, called direction switches, whose coils are energized by contacts (not shown) on car switch G; G, car switch with contacts for energizing the coils of the low speed switch, K, and the high speed switch H.

In operation, the car is usually started by bringing the switch directly to the high speed point, the motor starting and accelerating on the high speed winding without going through the low speed winding, which is used for retarding, though it is possible to run steadily, if need be, on low speed.

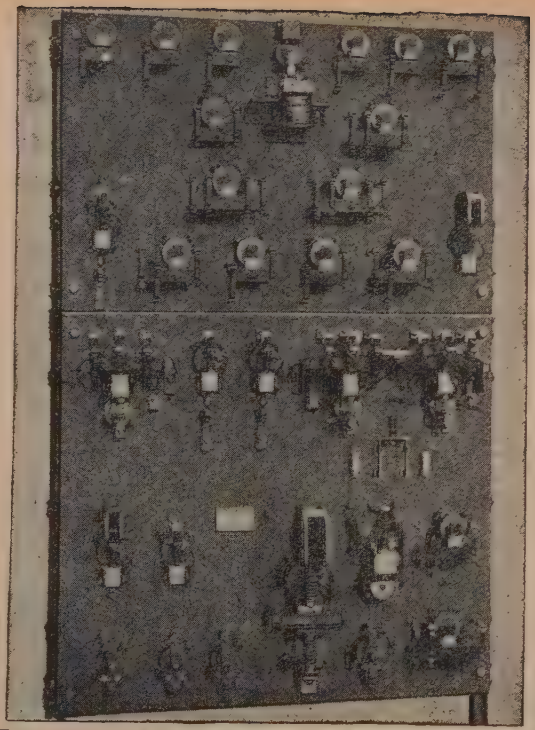
On retarding, the switch is moved to the low speed point, opening winding B, and inserting winding C, with buffer resistance E, in circuit, which is cut out automatically in several steps. Even if the car switch be brought at once to neutral on stopping, automatic devices (not shown) cause winding C, to be inserted for a short but definite time, to insure dynamic retardation to low speed before the mechanical brake L, is applied.

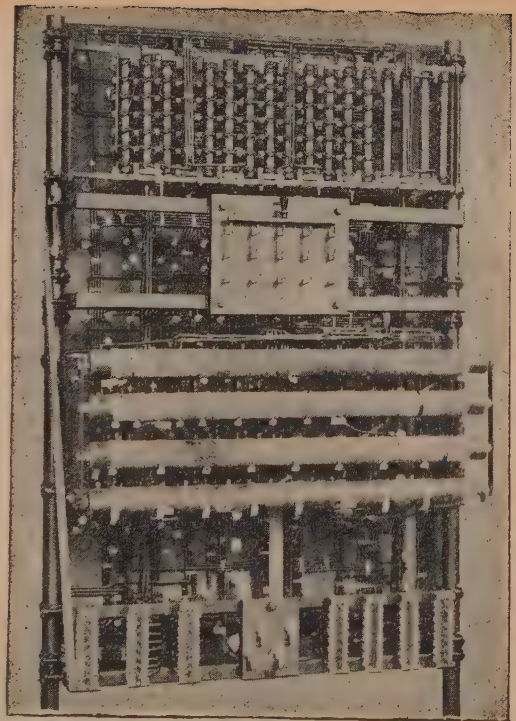
L, is the coil of the mechanical brake. If this be *a.c.* it is connected inside switches F; if *d.c.* it is connected to a magneto dynamo set through a contactor which is in turn connected inside switches F. M, is a main line or voltage switch.

Variable Voltage Control.—This control is also called *unit multi-voltage control* and was formerly called Ward-Leonard control.

In the variable voltage system *the elevator motor is always a d.c. machine.*

Each elevator has a motor generator set, thus having in effect its own private source of current, the voltage of which is varied at will to change the speed of the elevator.





FIGS. 6,795 and 6,796.—***Westinghouse variable voltage control system 1.*** *Contactor panel, front and rear views.* ***In operation,*** the car starts in the usual way by throwing the car switch to the running position. When it is desired to stop at any floor, the operator releases or returns the car switch handle to the center or off position.

The motor which drives the dynamo of the motor generator set is a constant speed, continuous running machine, and may be either a *d.c.* motor or an *a.c.* motor.

Hence the variable voltage system is independent of the source of current, and the performance of the elevator is the same whether the building has *d.c.* or *a.c*

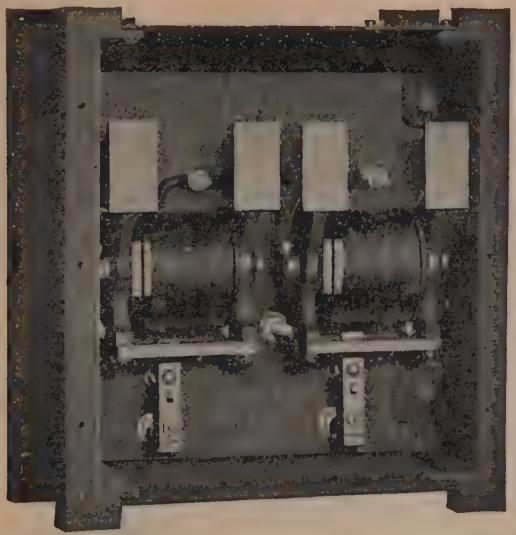


FIG. 6,797.—***Westinghouse variable voltage control system 2.*** *Inductor switch, cover removed.* ***In construction,*** there are two contacts, each operated by a coil and magnet. Iron plates, called inductors, mounted in the hatchway, close this magnetic circuit, when the car brings the switch opposite these inductors. Then the switch magnets move forward and open a control circuit causing the car to slow down. As stationary and moving parts never come into physical contact, noise and operating troubles are avoided, even at the highest car speed. The operating parts are enclosed in a cast iron box with cover of non-magnetic material (brass) giving protection against dust and dirt.

The dynamo of the motor generator set is a special constant speed variable voltage machine.

The car switch by which the elevator is operated, is in effect a combined reversing switch and field rheostat, as the car switch

points cut resistance in and out of the dynamo field to lower or raise the dynamo voltage and so slow down or speed up the elevator.

When the elevator is at rest there is no current flowing in the dynamo field; at full speed the dynamo field is at full strength. Weakening the dynamo field lowers the elevator speed.

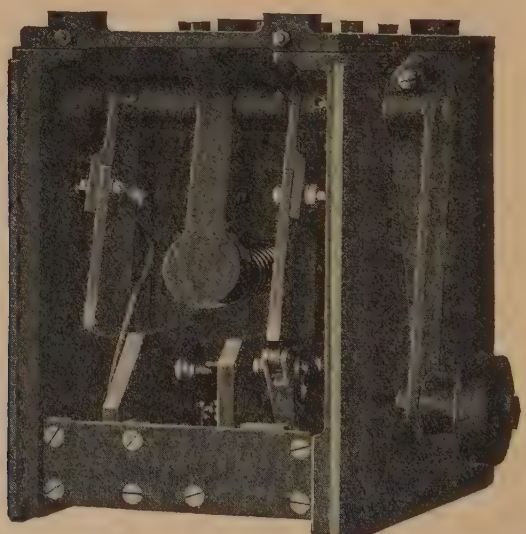


FIG. 6,798.—***Westinghouse variable voltage control system 3.*** *Landing switch.* ***It has*** three contacts enclosed in an iron box. These contacts are closed by an operating arm with rubber tired roller that engages cams in the hatchway. A magnet with an exciting coil holds the operating arm away from the hatchway cams at all normal operating speeds of the car.

Practically all gearless elevators to-day use variable voltage control. Formerly a great many gearless machines used rheostatic control, but very few are to-day being installed.

The majority of geared machines use rheostatic control (chiefly *a.c.* single or two speed because of the wide spread prevalence of *a.c.* distribution)

but a considerable and increasing number of geared machines use variable voltage control, especially at speeds 300 to 500 *f.p.m.* for passenger service, and 150 *f.p.m.* and higher for heavy duty freight elevators.

Variable voltage control has no losses in resistances during acceleration and retardation, hence the energy consumption is lower than with rheostatic control if the duty be severe; that is, many stops per mile.

FIG. 6,799.—***Westinghouse variable voltage control system 4. Car switch.*** This acts as master switch, controlling the direction and speed of movement of the car. An operating handle is rigidly connected to an arm which moves in a circular path, making necessary contacts. An emergency safety switch is supplied, which can be operated to make emergency stops, independent of the automatic floor landing control.

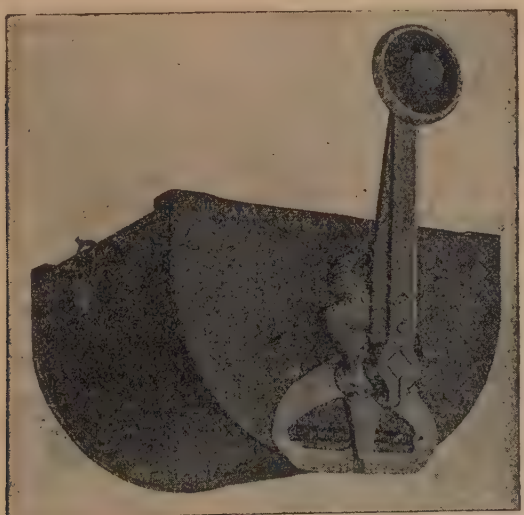
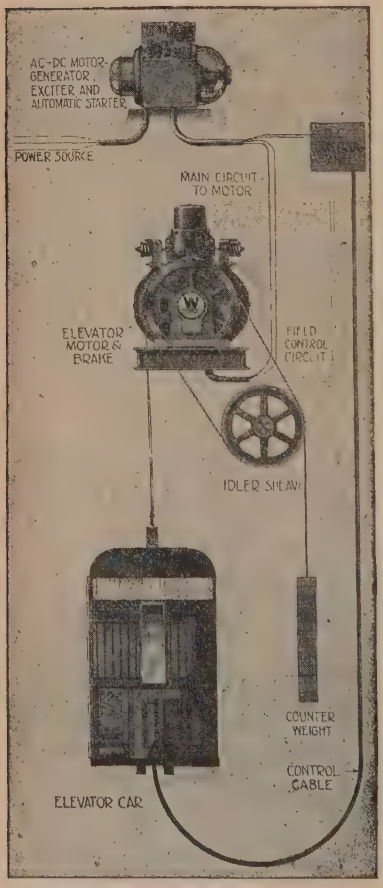


FIG. 6,800.—***Westinghouse variable voltage control system 5. Car slow down switch.*** This limit switch similar in construction to the landing switch is mounted on top of the car. An operating arm actuated by properly located cams, opens and closes the control circuits, causing the car to automatically slow down and stop at the extreme limits of travel.

Where the power supply is alternating, the motor generator set of the variable voltage system has a direct connected exciter, to supply a source of constant voltage direct current for the traction motor, the brake solenoid and the control magnet coils.



The controller for a medium or slow speed variable voltage system, with car switch operation is a very simple one.

It includes, first, an automatic starter with overload relay for the motor of the motor generator set. Then there are the two direction switches, or reversing contactors, for determining the direction of motion.

An emergency stop switch, or dynamic brake contactor is furnished, to open the loop circuit between motor and generator and apply a dynamic brake on an emergency stop; this switch is not actuated on regular operation. A brake relay, accelerating relay, and overload relay usually complete the list.

The field resistances are connected to the car switch contacts, also to the slow down limit switches, as shown in fig. 6,793.

FIG. 6,801.—Westinghouse complete variable voltage control equipment applied to traction elevator.

As in all other forms of multi-speed or two speed elevator control, the major part of the retardation of the elevator is dynamic, or what may more properly be called in this case, regenerative braking. The mechanical brake is applied only at the very last, when there is an inch or so to go before the car stops.

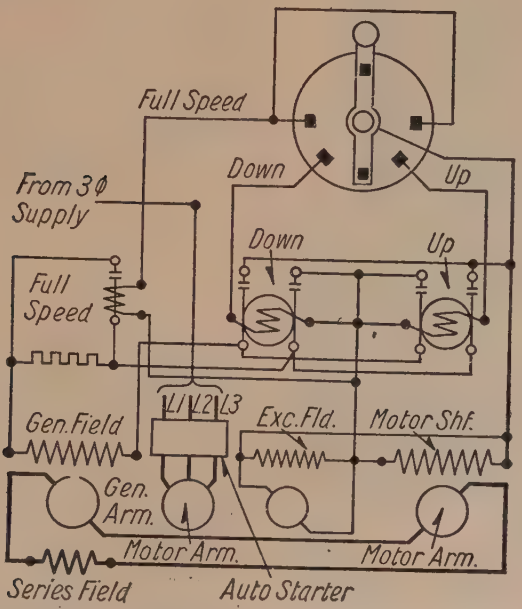
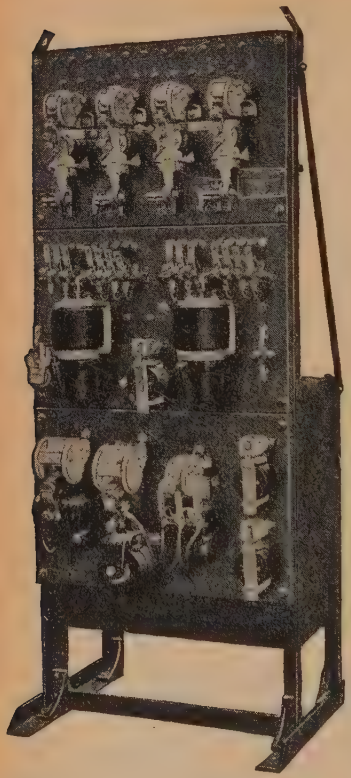


FIG. 6,802.—Elementary wiring diagram of Westinghouse variable voltage control. ***In operation*** the car is started in the usual way by moving the car switch handle to the running position. Control circuits are thereby established that close the directional switch and the dynamo field contactors on the panel. The dynamo field contactors establish a dynamo field current, which causes the car to move at a speed proportional to the voltage. The dynamo voltage builds up gradually but quickly and the car accelerates automatically smoothly and rapidly. The contactor panel has one single pole contactor in the armature circuit, between the dynamo and elevator motor, which closes before operation begins and opens after the elevator motor stops. This contactor is an essential safety feature because it prevents any possibility of the dynamo building up on residual magnetism after a stop is made. Two double pole contactors with mechanical interlock reverse the dynamo field circuit and thereby control the direction of the car. One contactor with a back contact controls the brake circuit. This brake circuit is so arranged that both sides are disconnected when the reversing contactors are open. In case of failure of current through the elevator motor field, or of power to the motor generator the elevator motor is completely disconnected and the brake is set automatically.



Principles of Variable Voltage Control.—This method of control is shown in fig. 6,804, which is a schematic diagram showing only the basic circuits.

In the figure A, is the elevator motor; with a shunt field E, separately excited, B, variable voltage dynamo with a shunt field F (also separately excited), and a series field S. C, motor which drives the dynamo; D, exciter (and O

FIG. 6,803.—Cutler Hammer variable voltage controller panel. ***In operation*** it changes the voltage of the dynamo of a motor generator set by field control, thus altering the speed of the elevator motor by varying the supply voltage. When the car switch is moved to the first speed position, the field and brake relay and either the up or down direction contactors close, providing full field for the elevator motor, releasing the brake, and energizing the dynamo field with all of its field resistor in circuit. The field resistor is so designed that the voltage generated, when it is all in series with the field, will be such that with full load on the elevator car the elevator motor will turn over very slowly. In the second speed position of the car switch, the first field relay is energized and operates gradually to short out five steps of field resistor. The time required depends upon the oil dash pot, which is used to retard the closure of this field relay. The voltage then generated is sufficient to operate the elevator at one half its full speed. With the car switch in the third speed position, a second field relay similar to the first is energized and this operates to gradually short out the remainder of the field resistor so that the elevator car accelerates smoothly to full speed. While running at full speed the operator may move the car switch back to any position, and the elevator car will automatically decelerate to the speed corresponding to the position of the car switch. In case the operator move the car switch from the full speed to the off position, or full speed in the other direction, the relays and contactors on the controller will automatically operate in the proper sequence due to interlocks, and the elevator car will decelerate, stop or accelerate without a jerk. Over speed of the elevator motor on an overhauling load is prevented by a compound wound relay, which operates to insert resistance in series with the dynamo field, thus reducing the voltage and causing the motor to slow down.

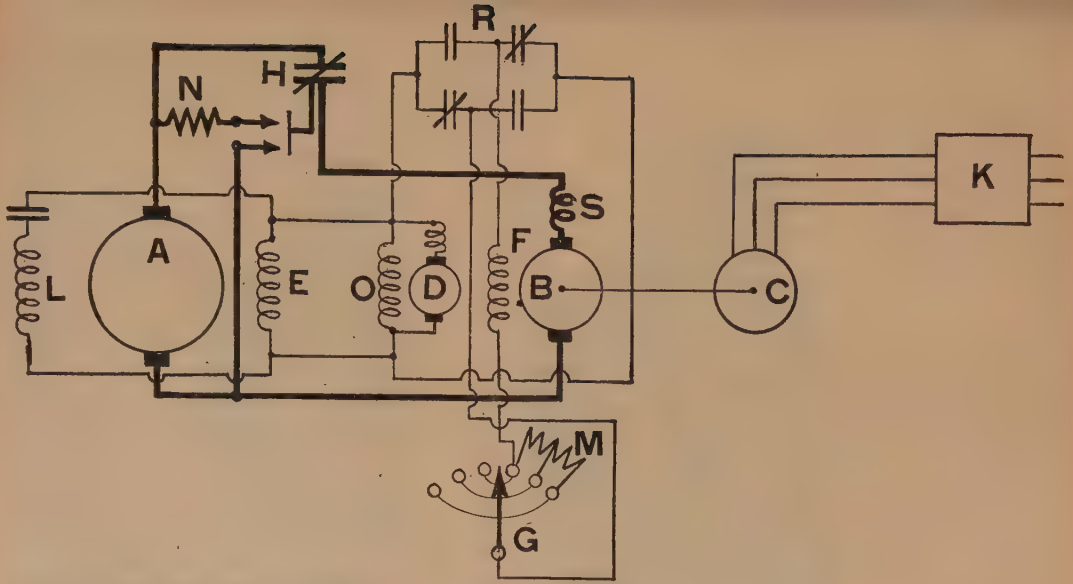


FIG. 6,804.—Elementary diagram of basic circuits for a variable voltage system.

its self-excited field) for supplying current for the dynamo field, elevator motor field, brake L, and control magnet coils; R, reversing switch by which the field F, is reversed—this reverses the voltage of the dynamo B, and so reverses the rotation of elevator motor A, to reverse the travel of the car.

R, is usually a pair of double pole magnetic switches whose coils are energized through contacts (not shown) on car switch G. This switch has contacts for inserting resistance M, in the field circuit F.

In operation, when resistance is inserted in F, it weakens the dynamo field, which lowers the dynamo voltage, and so lowers the speed of elevator motor A.

The circuit between the armature of dynamo B, and elevator motor A, is normally kept closed, the elevator being started,

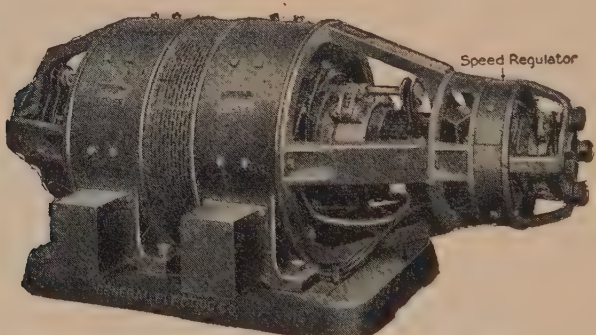


FIG. 6,805.—General Electric motor dynamo set of variable voltage control system with *d.c.* source of supply showing speed regulator.

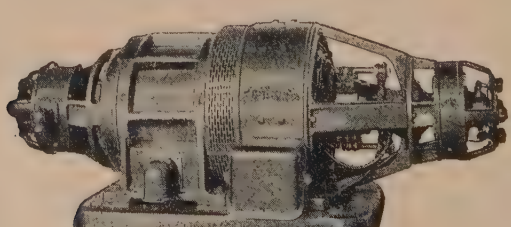


FIG. 6,806.—General Electric motor alternator set for *a.c.* source of supply.

stopped and reversed by switches R. However, in emergencies, the double throw switch H, is opened, opening the circuit between B, and A, and applying dynamic brake N. K, is the starter for motor C; L, solenoid coil of the mechanical

brake on A. The brake is applied by spring pressure and released by the magnet. Hence L, is energized when the motor A, is moving.

Automatic Leveling.—To properly understand automatic leveling, it is necessary to consider regulation.

Regulation, as applied to elevator control means the *tendency of the elevator motor to maintain its speed with changes of load, after the speed has been adjusted or set at any point.*

Thus full speed regulation of an elevator with a rated speed of 600 *f.p.m.* means the extent to which the actual speed departs from 600 *f.p.m.* hoisting and overhauling, at different loads.

If the speed never fall below 570 *f.p.m.* or rise above 630 *f.p.m.* under any conditions of load, the regulation is said to be 5% (30 *f.p.m.* is 5% of 600 *f.p.m.*)

Automatic leveling is primarily a problem of regulation on low speed, or first point of control.

Consider a gearless rheostatic control on the first point of the car switch. There is a good deal of resistance in the circuit. The load on the elevator affects the current and the current affects the voltage drop in the resistance and this in turn determines the voltage in the armature which in turn determines the speed. Hence the speed varies widely with the load.

Now assume a switch contact to be established in the hoistway at a certain fixed distance from the floor, just about far enough away so that under average conditions the elevator could come to a final stop under the brake if the power be cut off and the brake applied by this switch contact. Then run the elevator on the first point of the car switch, that is, at lowest speed. Because of the poor regulation in low speed, the speed of the elevator will vary widely with different loads, and so when this fixed cut off switch acts, the slide or drift of the elevator under the brake will also vary widely. Sometimes the platform will be level with the landing, sometimes above it, sometimes below it.

Now assume that the elevator control to be such that on the first point or lowest speed the speed is always just the same, regardless of load. Then the drift or slide after cut off by the fixed switch contact in the hoistway

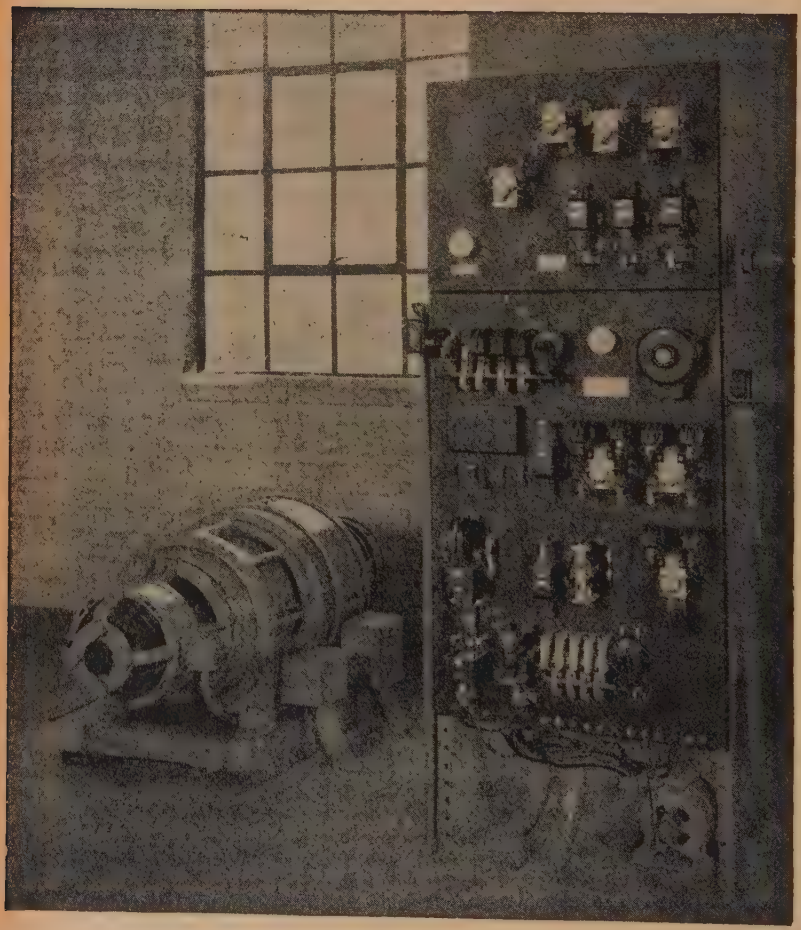


FIG. 6,807.—General Electric variable voltage control system consisting of a motor dynamo set and controller for elevator having automatic leveling devices.

would be more nearly uniform. It would not always be just the same, because this drift itself is influenced by the load. However, it would be close enough for accurate leveling.

The problem of leveling is 1, to get good regulation on the lowest speed and 2, to get a suitable device for influencing the control at fixed points in the hoistway.

Auxiliary Motor Micro-drive.—One method of getting good regulation on the first point is used in the *auxiliary motor micro-drive*. In this system *a small constant speed motor is geared down so as to drive the elevator at an exceedingly low speed (low enough so as to make a final stop from this speed in a very short distance) just before stopping.*

This motor, because it runs without resistance at its most favorable point, has very close regulation, and the low speed or leveling speed is substantially independent of load.

The auxiliary motor is not geared permanently to the main motor, but is connected only when leveling, by means of an electric clutch, which also acts as a brake on the main motor.

Automatic Leveling with the Main Motor.—With variable voltage control the regulation on the low speed or first point is so close that a low speed for leveling can be obtained without an auxiliary motor, merely running the main motor on very low voltage. This regulation under these conditions is suitable for leveling provided the apparatus be not worked too close to capacity; hence variable voltage equipment for automatic leveling is sometimes built larger than for non-leveling duty of the same rated load.

Automatic Leveling with Two Speed Motor.—Under certain conditions automatic leveling can be obtained with a two speed *a.c.* motor. A low speed winding can be selected which gives

low enough speed for leveling (provided the rated speed of the elevator is moderate) and this speed will be reasonably constant with changes of load. The inherent regulation, however, is not as close as with variable voltage control.

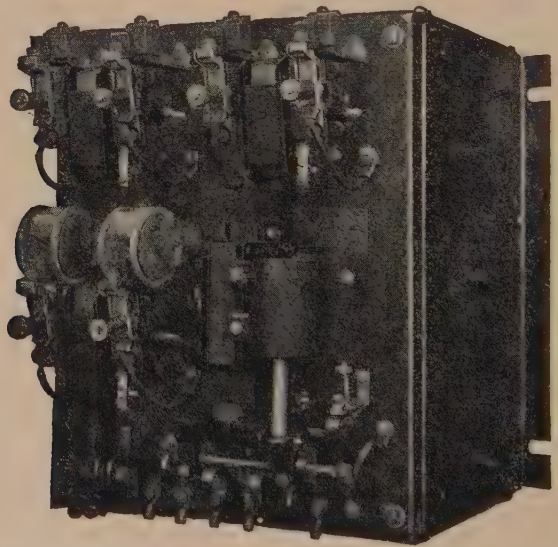


FIG. 6,808.—Cutler Hammer semi-magnetic control panel for slow speed elevators driven by slip ring induction motors. ***It consists of*** an automatic starter and a separately mounted reversing switch. Motor acceleration is controlled by an adjustable time limit relay. When the dashpot on this relay is once set, the starter will always cut out the resistor in the same length of time. The accelerating relay on the automatic starter operates the pilot circuit contacts of the accelerating contactors. If this controller be used on a winding drum type elevator, the traveling nut on the elevator machine should be arranged to throw the drum reversing switch to the off position at the normal limits of travel. For traction type elevator machines, two hoistway limit switches may be used for obtaining the terminal stops. All controllers of this type are arranged for the operation of either a single phase or a polyphase magnetic brake. When such a brake is installed, hoistway limit switches are recommended in place of the more expensive traveling nut device. In any case, all installations should include two hoistway limit switches to prevent overtravel of the elevator. In order to prevent the automatic starting of the elevator upon resumption of voltage after failure, when the shipper mechanism is left in the running position, a low voltage protective relay should be added to the standard equipment, two relays on two phase, four wire installations. This relay will also prevent the starting of the elevator car upon the closure of a gate or door, where door switches are used, without first moving the drum reversing switch to the neutral and then to the running position.

Automatic Leveling Devices.—Reference has been made to a switch in the hoistway at a fixed distance from the landing to cut off power at the proper place. Substantially this principle is widely used on low speed elevators. The device usually takes the form of suitably placed cams for each floor, and a switch carried on the car, with an arm and roller to engage the cam. When a stop is to be made the switch contact is in circuit. When no stop is to be made the switch contact is ineffective

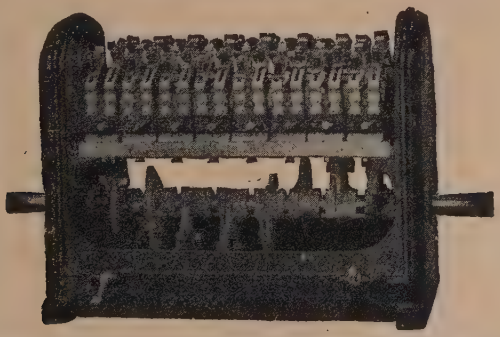
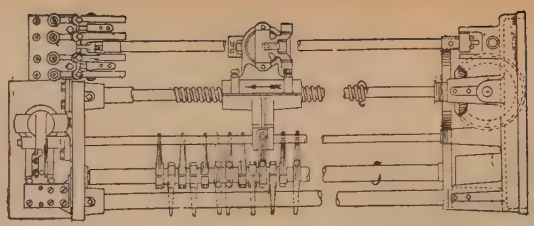
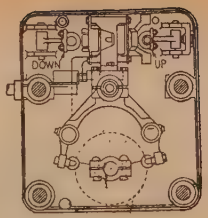


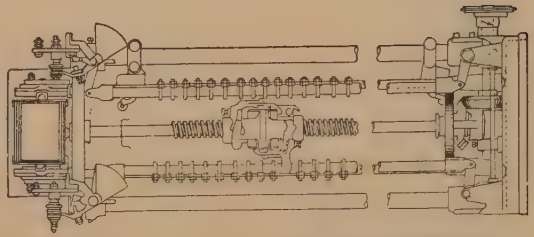
FIG. 6,809.—Cutler Hammer *a.c.* or *d.c.* floor selector for push button controlled elevators or dumb waiters with or without slow down. They can be used with either winding drum or traction type elevators. ***For traction type elevators*** a separate small winding drum must be geared to the selector. This drum should be operated directly from the elevator car by means of a cable so that the accuracy of stops will not be disturbed by the shifting of the traction cables on the driving sheave. This applies to the V groove as well as the wrap traction elevators. ***For winding drum type elevators,*** the selector may be geared directly to the elevator winding drum shaft. It is recommended, however, that the separate small winding drum be used for this type as well as for the traction type. This arrangement has a distinct advantage in that it automatically compensates for stretch of the hoisting cables, thereby eliminating the necessity of adjusting the selector to compensate for the stretch of the cable. A sprocket wheel and a long chain may be used instead of the winding drum and steel cables, if desired.

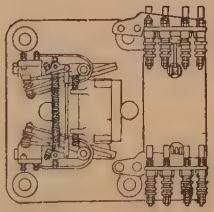
even though the cam caused the usual movement of the switch arm.

This device is widely used on push button elevators as a stopping switch. The difference between a straight push button elevator and an automatic leveling push button elevator lies chiefly in the provision for a very low stopping speed in the latter, with close regulation on this speed.









FIGS. 6,810 to 6,812.—General arrangement of Otis micro-selector.

With the cam roller switch type of leveling and stopping device, the switch arm is sometimes arranged to be retracted by mechanical means (by a magnet or motor) when no stop is to be made, to prevent wear and tear on the parts, but this device is seldom used because the cam roller switch type is generally employed only on low speeds.

At high speeds, where the engagement of the roller with the cam would be objectionable due to noise and wear, other types of leveling device are usually employed

Floor Selector Type.—The floor selector type of leveling device in effect *reproduces on a small scale, in the machine room the motion of the elevator in the hoistway.*

It is equipped with contacts located to correspond to the various floors, and arranged to actuate magnets on the controller at the proper time and place (that is, corresponding to proper place in the hoistway) to produce low speed and then to stop the elevator.

Floor selectors are of many types, some having sliding contacts in a plane, with a brush carriage or cross head carried on a traveling nut on a screw; some having contacts actuated as a result of rotary motion around a shaft; and others having various combinations and variations of these two fundamental forms.

Floor selectors are sometimes driven direct from the elevator car by tape or cable, and sometimes from the hoisting machine or secondary sheave. In the latter case, a re-set, or corrective device is usually provided to keep the selector in synchronism with the movement of the car, and to correct for rope slippage.

Floor selectors are also sometimes called signal machines, especially where automatic leveling is provided as a part of signal operation.

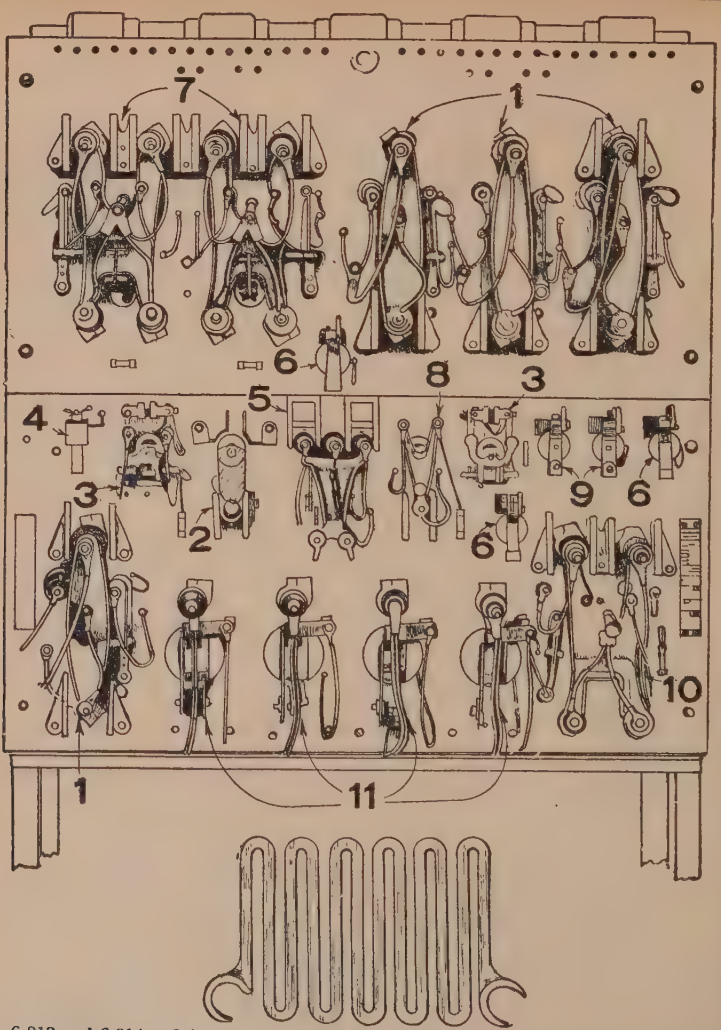
Hoistway switching devices operating without mechanical contact.—There are two forms of such devices used in automatic leveling:

1. Vacuum tube;
2. Inductor.

Both forms work generally in the following manner:

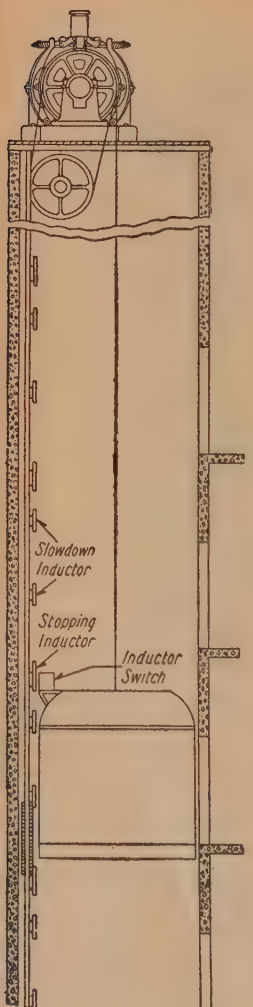
The tube or inductor (or several of them), are mounted on the car, while at suitable points in the hoistway, steel plates are mounted, so that at the proper place with respect to a floor at which a stop is to be made, the device in the car will come opposite (or go by) a plate, whereupon relays are actuated, to produce the required action on the elevator, for slow speed, or stop.

It is merely necessary for the device on the car to be close to the plate (but not touching it) in the case of the inductor, or to span the plate (with



FIGS. 6,813 and 6,814.—Otis type DGS controller and detail of grid resistance. 1, fast speed magnets; 2, breaking sw; 3, relay sws; 4, overload relay; 5, making and breaking sw; 6, WA magnets; 7, reversing sw; 8, main line sw; 9, W magnets; 10, potential sw; 11, accelerating magnets

FIG. 6.815.—General Electric vacuum tube or pliotron leveler as used with General Electric automatic control; view of top of car showing pliotron units. Automatic leveling with this system is accomplished with the main traction motor without hatchway cams, or rollers, or cab mounted retiring cams, or any electric contacts made or broken in the hatchway or on the car. The leveler consists of: 1, fixed steel plates suitably mounted in the hatchway, having no electric circuits and no mechanical contact; 2, leveling units, known as pliotron units, mounted on top of the car. No contacts are made or broken in these units, and they have no moving parts; 3, relays on the control panel. For car switch control with automatic leveling, four relays are added as compared with ordinary manual leveling, regardless of the number of floors served. The parts mounted in the hatchway at the various floors consist of plates $\frac{1}{4}$ in. thick, and usually less than 2 ft. in length. Because the leveler operates by the damping of an oscillating circuit, causing abrupt rise of current to operate the relays, and involves no make and break contacts and no inductor or reactor control, its response is practically instantaneous. The leveler acts directly on the main traction motor and involves no auxiliary driving mechanisms, gears, clutches, or brakes. Accurate leveling with one motor is possible, largely because of the inherent design of the motor itself and the immediate response of the pliotron control. This leveler is applicable not only to straight car switch control but also to control where the operator may automatically effect a landing at the floors in response to signals pre-registered from the calls made in the hallways, or to the wishes of the passengers in the car.



a substantial air gap on each side) in the case of the vacuum tube, to bring about the required action on the control.

The inductor consists of a sort of relay, normally open, which becomes closed as the result of magnetic action when the plate passes it.

The vacuum tube, or pliotron, is a three-element tube, with filament, grid and plate. Projections from the box holding the tube contain flat circular coils which are in the grid and plate circuits respectively. A relay on the controller is in the plate circuit. A current is always flowing in the plate circuit when the elevator is running, but this is an oscillating circuit of very low value, and cannot operate the relay till the oscillations are damped. Passage of the unit containing the tube and coils past the plate in the hoistway damps the oscillations, and instantly actuates the relay on the controller.

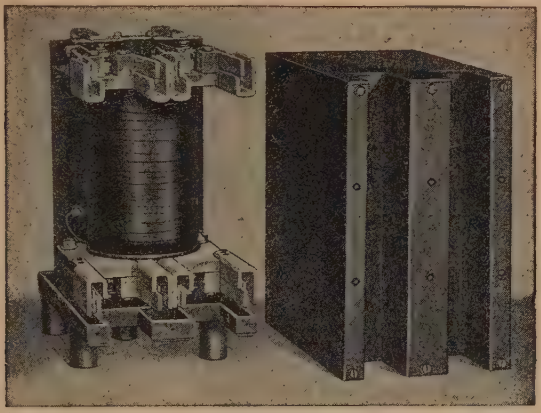
Elevator Operation.—The three basic methods of elevator operation are:

1. Manual operation;
2. Push button operation;
3. Signal operation.

Manual Operation.—This is the correct name to describe what is often spoken of as a car switch control, or switch control or hand control. The

FIG. 6,816.—Automatic inductor control system showing Westinghouse traction elevator installation with variable voltage control. ***In construction,*** inductor switches mounted

term control, however, is properly limited to the method of speed variation, as rheostatic control or variable voltage control.



FIGS. 6,817 and 6,818.—Westinghouse inductor switch with cover removed.

FIG. 6,816.—*Text continued.*

upon the top of the car are used to give automatic control without any mechanically operated devices. There is one set of inductor switches for the up direction and another for the down direction. Only part of the magnetic circuit of the inductor switch is on the car. To complete the magnetic circuit the inductor switch must come opposite an iron plate or inductor in the hatchway. The car is started in the usual way by moving the car switch handle to the running position. When it is desired to stop the car at any floor the operator returns the car switch handle to the center or off position. The coil of the inductor switch is thereby energized and as the inductor switch passes the inductor plate in the hatchway the armature of the inductor switch magnet is pulled toward the inductor plate, thereby opening the circuit to the relays on the elevator control panel, slowing down and stopping the car. The inductor switches operate in sequence as the car approaches the floor, slowing it down smoothly and rapidly, the final one stopping the car at the floor level. The iron plates or inductors in the hatchway are fastened by clips to the counterweight or car rails. There is one set of inductors for each direction of travel. They are placed the same distance from each floor, giving the operator a zone equal to the distance between floors in which to center the car switch handle to stop the car at any floor. When the car switch handle is centered, the inductor switch coil is energized but will not operate until the car has reached the point where the inductor switch is opposite the inductor in the hatchway. This point is the minimum distance from the floor in which the car can be slowed down rapidly but smoothly and stopped accurately at the floor level. When making floor to floor runs the operator moves the car switch handle to the running position and immediately returns it to the off position. In this case the high speed relays of the control are not energized and the car speed builds up to an intermediate value which is so proportioned that a run can be made from one floor to the next in the minimum time. In this case the inductor switch is actuated by an inductor midway between the floors, so that the car attains its maximum speed for a one floor run.

Push Button Operation.—This method of control is of three basic types:

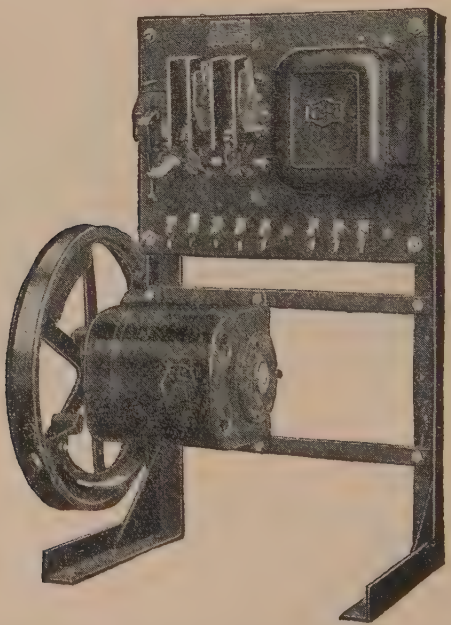


FIG. 6,819.—Cutler Hammer *a.c.* semi-magnetic elevator controller, single speed, across-the-line type, with combined reverse and master drum switch self contained, for slow speed freight service. ***It consists of*** a magnetic contactor panel and a combined reverse and master drum switch, mounted on an angle iron floor type frame. The contactor panel contains the main line magnetic contactor and the phase reversal relay. The combined reverse and master drum switch contains the reversing contacts and auxiliary contacts for handling the main line contactor. The drum switch is mounted below the panel on heavy supporting bars and can be easily turned around so that the sheave wheel is at the right or left of the panel as desired. ***In operation*** moving the combined reverse and master drum switch to either the up or down running position connects the phases in their correct order for up or down operation. Auxiliary contacts in the drum complete the circuit to the coil of the main line contactor, releasing the brake and starting the motor. Returning the switch to the off position breaks the motor circuit and sets the brake. Reversing of the motor is accomplished in the drum switch. The phase reversal relay prevents starting of the motor if the line phases be accidentally reversed. Reversing of the phases would cause the elevator car to start in a direction opposite to that in which the operator expects it to move. Under these conditions, the relay prevents the motor starting until the phases have been reconnected in their normal order.

1. Hold in push button operation;
2. Full automatic push button operation;
3. Dual operation.

Hold in Push Button Operation.—In this system *up and down buttons are mounted in the car and also at each landing.*

FIG. 6.820.—Cutler Hammer (all magnetic, single speed push button a.c. controller panel installation showing elevator machine. When push button control is used the car is sometimes "stolen" before the person in it has had a chance to open the car gate or door after arriving at its destination. To overcome this objection a non-interference relay may be used to provide ample time for opening the gate or door.

Pressure on an up button, for example, starts the car up, and it runs only so long as the button is held depressed. When the button is released, the car stops. Hence this system is applicable only to low speed elevators. Provision is made to prevent operation by the landing buttons when the car is in motion as the result of pressure on one of the car buttons. This system

is widely used for freight elevators at 100 *f.p.m.* or less. It is sometimes called *double button control.*

Full Automatic Push Button Operation.—In this system *buttons are mounted in the car corresponding to each floor. Buttons are also mounted at each landing.*

Pressure of a button starts the car, which then continues to run after the button has been released, and stops automatically at the floor corresponding to the button pushed.

A specialized form of full automatic push button operation is the *collective or interceptive operation.*

In the straight push button operation when a button has been pushed, the car is entirely under control of that one button, and cannot be stopped or intercepted by another button (except when the emergency stop button in the car has been pushed, which cancels all calls, including the one being answered at the time).

FIG. 6,821.—General Electric car operator's switch and push button panel for pliotron unit automatic control. In operation passengers entering the car make known the floors at which they will leave, and such calls are recorded on an operator's push button panel in the car. Thus, both outside and inside calls are registered in the same way, and the operator automatically receives a signal to stop in precisely the same manner, and at just the proper time, for inside as well as for outside calls. With this system of signals, in conjunction with pliotron unit control the operator need pay no attention to his position in the hoistway, in order to make a landing. Furthermore, the operator always receives the same signal to stop, and always makes the same simple movement of the car switch in response to this signal, so that response becomes automatic.

In the collective interceptive type of push button operation, however, the car can be started by pressing a button in the car, or at a landing, and it can afterwards be stopped or intercepted by another button, if that button be at a floor (or corresponds to such a floor, in the case of buttons in the car) in between the point from which the car started and the floor to which it was called or dispatched by the first button pushed.

Dual Operation.—Where push button operation is combined with manual operation in the same car, the combination is called dual operation.

An elevator with dual operation has a car switch, a push button station and an annunciator in the car, and a throw over switch on the controller so that, when on push button operation, the landing buttons will call the car, while on manual operation, the landing buttons will operate the annunciator.

A simplified and widely used form of dual operation is that called semi-dual.

In this system there is no car switch, but the annunciator and the throw over switch are retained. When an operator is on the car, the landing buttons operate the annunciator, and the operator runs the car by the car push buttons. Semi-dual operation is really necessary, as distinguished from straight dual operation, when the car has automatically operated cab doors.

With collective-interceptive control an operator may be engaged to run the car (so as to be helpful to passengers) without the need for an annunciator and hence without dual or semi-dual operation.

Signal Operation.—The term *signal operation* is the proper one to apply to that type of elevator operation *where the elevator is started by an operator, but where the stopping is brought about as the result of pressing one of the signal buttons.*

In addition to the stopping buttons on the landings, which serve for a bank of several cars, and which when pressed cause the first car of the bank approaching in the proper direction to stop, buttons are mounted in each car also, one for each floor served, which when pressed set up stop calls, or stop impulses for that car alone, the car stopping at those floors in proper order regardless of the order in which the buttons are pressed.

Signal operation, like push button operation, requires a floor selector or signal machine, and a relay panel, in addition to the regular control, for recording the stop calls, releasing the stop impulses at the proper time, cancelling the signals from the other cars, and resetting the relays after stops are made.

There must also be means for automatic leveling, which may be one or the other of the types previously described, either separate from the signal machine, or combined with it.

TEST QUESTIONS

1. *Name the two general types of control systems.*
2. *Is rheostatic control extensively used?*
3. *Name the various types of rheostatic control classified according to speed and type of motor used.*
4. *How are typical* d.c. *motors wound for speeds of* 200 *to* 400 f.p.m.?
5. *What is the feature of the* d.c. *motor with wide range field control?*
6. *What is the standard type motor for two speed* a.c. *rheostatic control?*
7. *Describe the braking action of an induction motor.*
8. *Is a* d.c. *brake solenoid preferable to an* a.c. *brake?*
9. *What are the features of the various types of two speed motors used?*

10. *Describe in detail the principles of rheostatic control.*
11. *Define variable voltage control.*
12. *What type motor is always used for variable voltage control?*
13. *What is the object of the motor generator set used in the variable voltage system?*
14. *Describe at length the variable voltage system.*
15. *How is the motor generator set arranged when the power supply is* a.c.*?*
16. *Draw elementary diagram of Westinghouse variable voltage control.*
17. *Define the word* regulation *as applied to elevator control.*
18. *What is understood by the term* full speed regulation?
19. *Upon what does automatic leveling depend?*
20. *Describe at length the methods of automatic leveling.*
21. *Of what does the auxiliary motor micro-drive consist?*
22. *Describe automatic leveling with the main motor.*
23. *How is automatic leveling obtained with two speed motor?*
24. *What is the difference between semi-magnetic and full magnetic control?*
25. *Describe in detail the various automatic leveling devices used.*

26. *Describe the vacuum tube and inductor systems of leveling.*
27. *Name three basic types of push button control, and describe them.*
28. *Define dual operation.*
29. *What are the requirements for signal operation?*

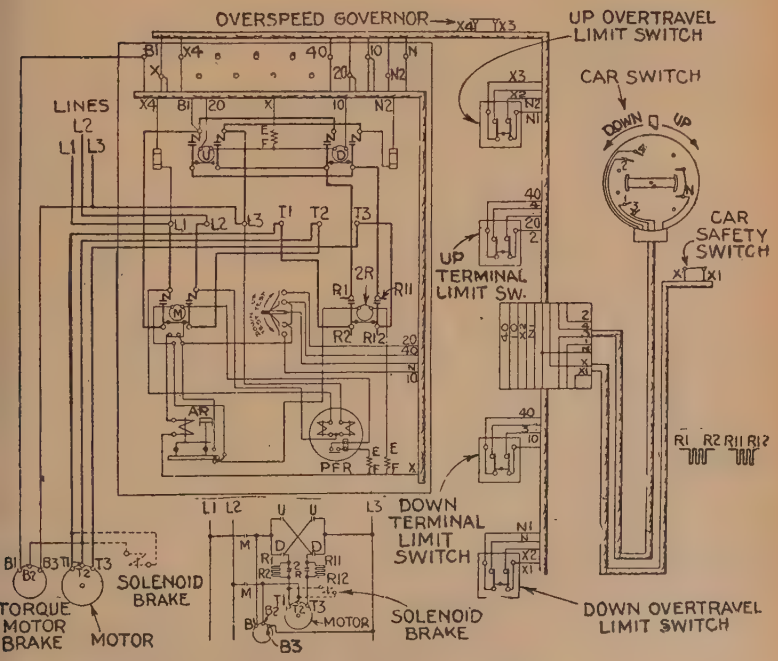
CHAPTER 157

Elevator Control Diagrams

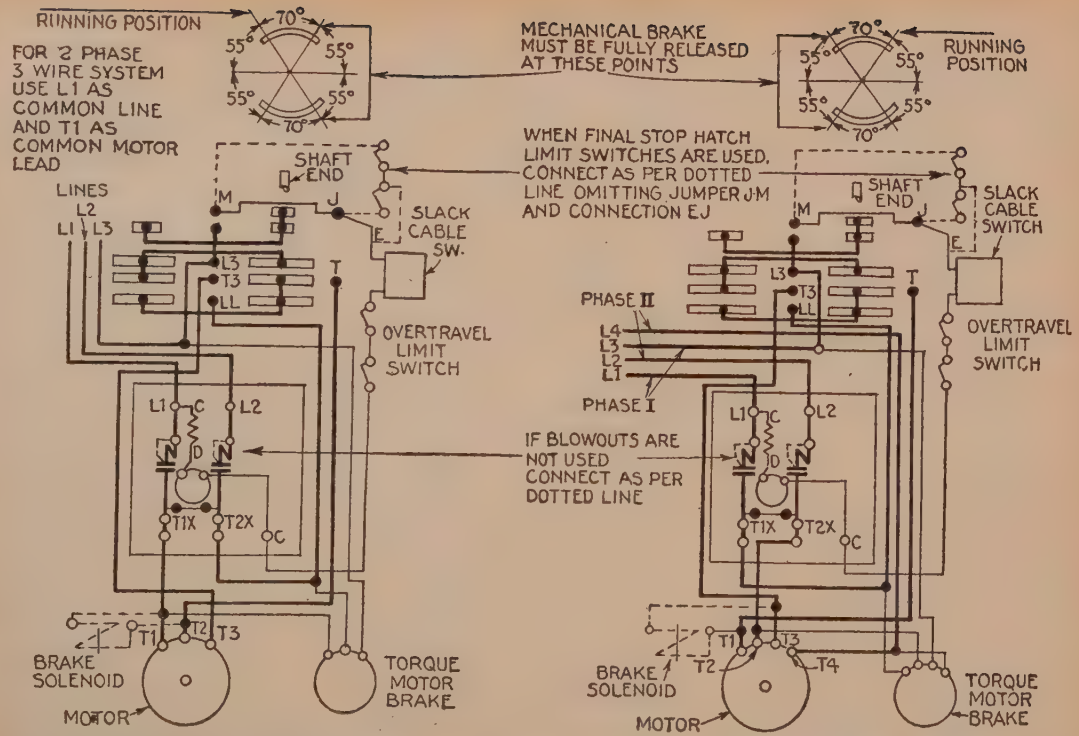
The following notation as given by Cutler-Hammer will be found useful in reading diagrams:

The lines should be placed sufficiently far apart to enable the wiring circuits to be traced without confusion.

(Text continued on page 4,168)



FIGS. 6,822 to 6,824.—A typical Cutler Hammer wiring diagram.



FIGS. 6,825 and 6,826.—Cutler-Hammer connections for *a.c.* semi-magnetic elevator controller. Fig. 6,825 three phase or two phase three wire; fig. 6,826, two phase four wire.

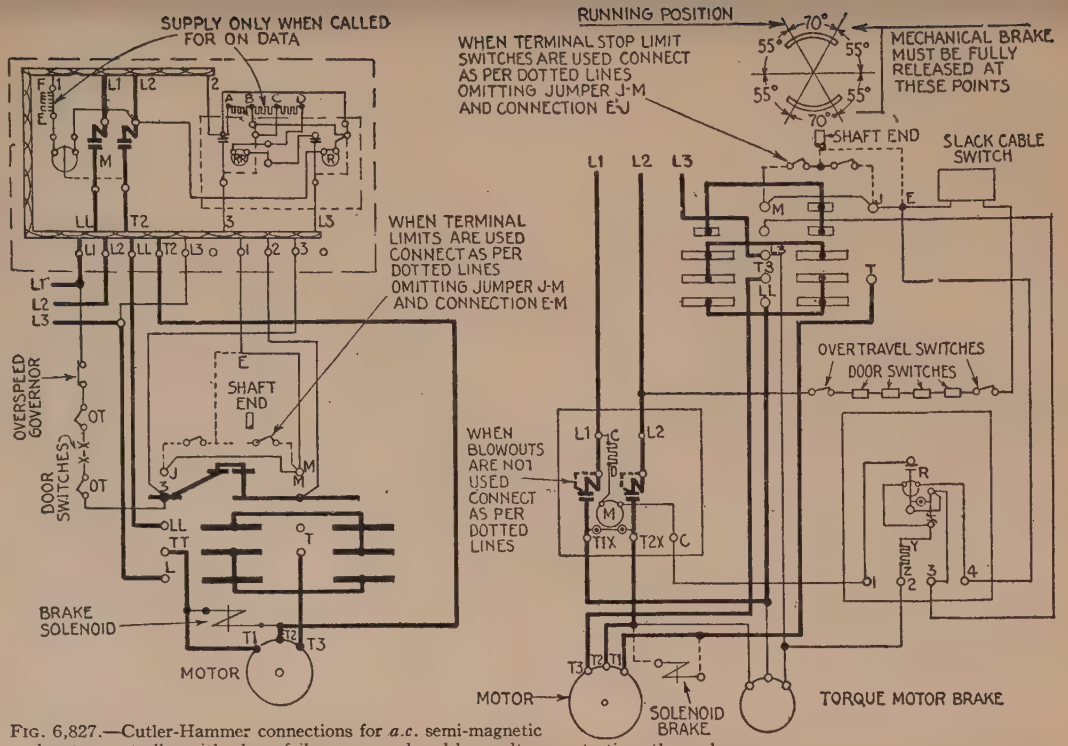


FIG. 6,827.—Cutler-Hammer connections for *a.c.* semi-magnetic elevator controller with phase failure, reversal and low voltage protection; three phase.

FIG. 6,828.—Cutler-Hammer connections for semi-magnetic elevator controller with low voltage and phase failure protection, for three phase or two phase, three wire.

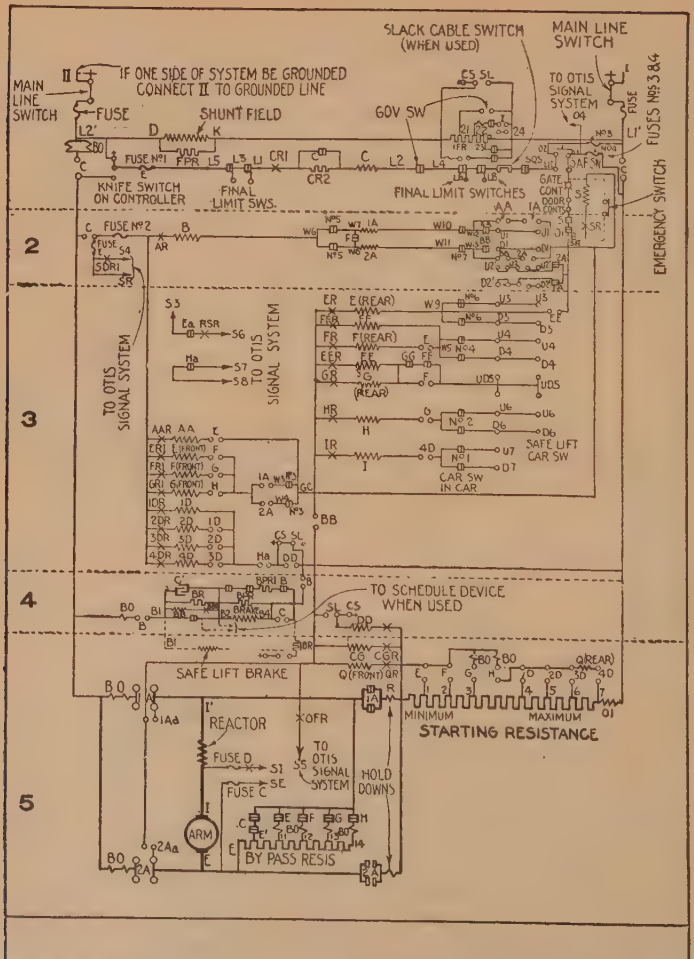
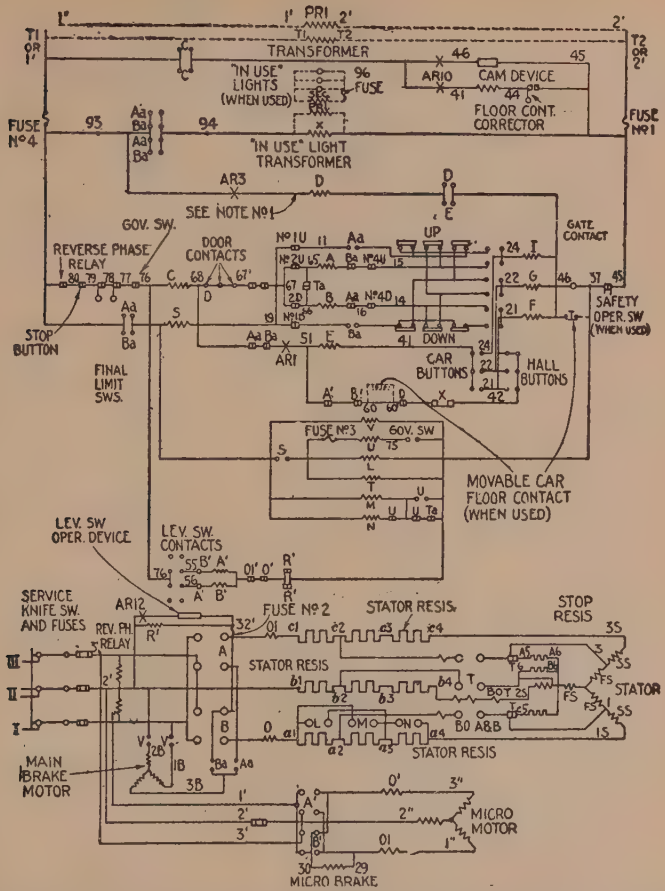


FIG. 6,829—Otis *d.c.* resistance controller for use with gearless traction machine, car switch operated with safe lift 1A, 2A, reversing switch; B, brake switch; C, potential switch; E,F,G,H, speed switches; 1D, 2D, 3D, 4D, accelerating sws; I, field switch; S, door contact relay; Q, load switch; AA, reversing sw. relay; EE, 1st speed sw. relay; GG, 3rd speed sw. relay; 01, overload relay; FF, 2nd speed sw. relay; BB, brake relay; DD, safe lift relay.



FIGS. 6,830 and 6,831—Otis magnet controller for micro drive worm gear traction machine. Three phase, three wire, two speed push button control. ***Names of switches. Main controller:*** A,B, reversing switches; C, aux. cam switch; D, self holding switch; E, non interference sw; F,G,I, floor switches; L,M,N, accelerating sws; S, aux. fast and slow speed sw; T, fast and slow speed sw; U, aux accelerating sw; V, aux. brake switch time limit relay; O,Cl, protective relays. *Micro controller.* A'B', reversing switches; O'O', protective relays; R', micro retarding switch. ***Note No. 1.***—If movable car floor contacts be used omit connection between D coil and AR3, resistance.

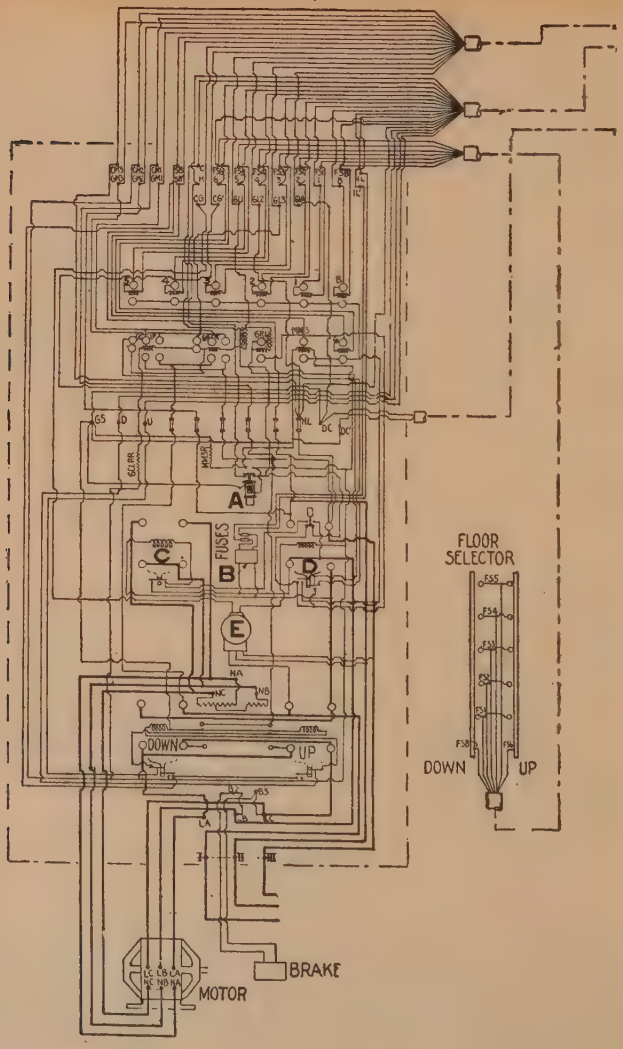
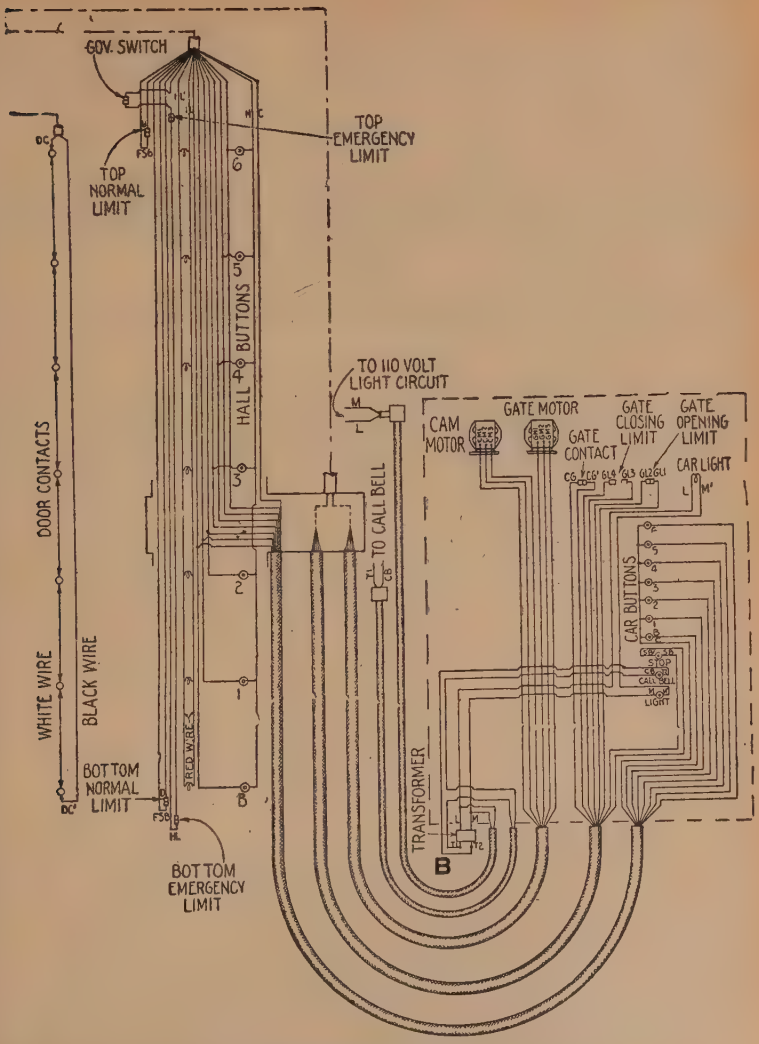


FIG. 6,832—Watson three phase controller for push button operation. A, time relay; B, trans-



former; C, accelerating switch; D, potential switch; E, reverse phase relay.

An elementary diagram should always be included; especially is this necessary on complicated diagrams. Overtravel and hoistway limit switches are shown on all diagrams. On drum machine control diagrams a slack cable switch is shown.

On *a.c.* wiring diagrams the connections for both single phase and polyphase brakes are indicated.

On *d.c.* diagrams connections for a compound wound motor and a compound wound brake magnet with the series windings cut out in one step after starting are shown. Optional connections for a shunt motor and a shunt brake are also placed on the diagram.

D.c. diagrams carry polarity signs, because of the fact that the carbon copper contacts have much longer life when the current flows from the carbon to the copper.

On all diagrams for showing full magnetic controllers control fuses are included. A try out switch is shown, except on two landing push button installations and on three landing dumb waiter installations.

The try out switch is connected outside of the terminal limits, so that it is possible to run into the overtravel switches from the try out switch. This method of connecting the try out switch saves running four wires from the limit switches to the control panel.

A single pole overspeed governor contact is shown on all diagrams. The car safety switch is connected to the line whose polarity is opposite to that which is used for the car switch, and the connection is made by a separate cable.

CHAPTER 158

Safety and Protective Devices

These may be classified as electrical and mechanical. The mechanical are so closely allied to the electrical that they will be briefly described. The principal safety devices are:

1. Guide grips;
2. Overspeed governor with governor switch;
3. Car operating switch;
4. Car safety switch;
5. Terminal limit switches;
6. Over travel limit switches;
7. Slack cable switch;
8. Door switches;
9. Compensating rope sheave switch;
10. Buffers and air cushions.

Guide Grips and Overspeed Governor.—Guide grips have been made in a number of different types such as eccentric, dog, roller, and wedge, *the wedge type now being almost universally adopted*, an example of this type being shown in fig. 6,833.

The mechanism, is mounted below the car with a small winding drum which is connected to the overspeed governor by a steel rope. The holding of this rope at excessive car speeds rotates the drum so that the wedges force the grips against the guide rails and stop the car.

Usually a fly ball type of governor is used in connection with the guide grips so arranged that the rope referred to rotates the governor shaft.

The governor is arranged with a grip so that if the normal speed of the elevator be exceeded by a fixed amount it holds the governor rope and effects the setting of the guide grips.

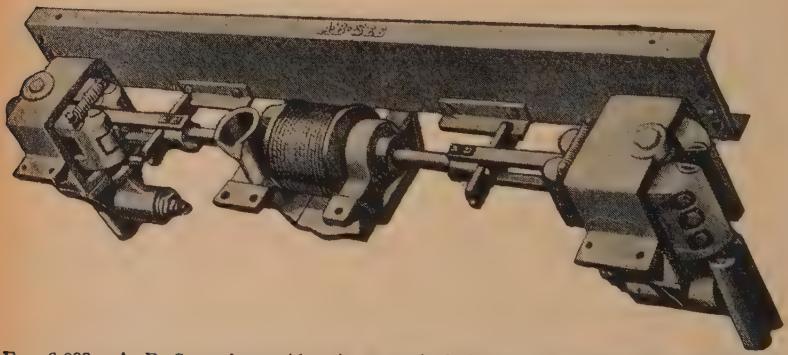


FIG. 6,833.—A. B. See safety guide grip or gradual clamp. *It consists of* a centrifugal governor connected by means of a wire rope to a clamping device which is located under the car platform. The whole apparatus is designed so that if for any reason the car should descend at a greater speed than that predetermined, and for which the governor is set, the elevator car will be brought to a gradual and smooth stop. This governor revolves at a speed corresponding to the movement of the car by means of a wire rope, one end of which is connected to the clamping device, located under the car platform, the rope is then led up the hoistway to the governor, over the governor driving sheave, thence down the hoistway to the tension sheave in the pit, under the tension sheave and back to the car where the other end is fixed. The clamping device is fastened securely to the lower members of the sling supporting the car platform and enclosure. It consists of a system of levers and wedges so arranged that when the governor brings the safety into action the guide rails on each side of the car are gripped between a pair of jaws. To prevent too rapid clamping on high speed elevators the construction is such that the jaws gripping the rails are actuated through a compression spring. This spring is graduated so that the distance the car travels, after the jaws have made contact with the guide rails, must be greater than that the car would fall through with a free drop, to attain the speed of car at the instant the safety is applied. For slower speeds than 500 ft. per min. the inherent elasticity of the various parts comprising the clamping device is sufficient to insure the required stopping distance.

It is accepted practice to install a control switch on the governor, so adjusted that the switch will trip to open the control circuit and disconnect power from the motor at a speed lower than the speed at which the guide grips act.

This switch prevents the guide grips setting in case of a slight overspeeding. The switch is arranged so that it cannot be reset unless the guide grips are in the running position.

Car Operating Switch.—This switch, shown in fig. 6,834, usually has *the automatic return or self centering feature so that if the operator's hands be removed from the lever it will return to the off position.* It is also usually provided with a center latch so arranged that any accidental leaning against the switch will not move the lever to the running position.

Car Safety Switch. — This switch is *for the purpose of stopping the car in emergency in case of the failure of the car operating switch.*

FIG. 6,834.—Westinghouse elevator car operating switch for variable voltage system in flush panel with auxiliary switch. Five operating positions are provided, giving speeds from a creeping speed up to full speed.

It is shown in fig. 6,835. It is wired in a separate cable of opposite polarity to the car switch cable, so that in case of grounds, etc., in the car switch cable, the car safety switch will not be thrown out of commission.

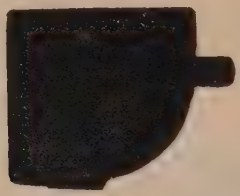


FIG. 6,835.—Cutler Hammer car safety switch for mounting adjacent to the car operating switch. It is a single pole switch and is connected in the control circuit on the side of opposite polarity to the car switch and insures a safe stop regardless of any possible combination of grounds. A separate two wire car control cable connects the switch with the control panel. Any grounds which are of a sufficiently serious nature to interfere with the operation of both the car switch and the safety switch will render the elevator equipment itself inoperative.

FIG. 6,836—Cutler Hammer door electric contact. Fig. 6,836 type is generally used where space limitations compel the installation of a small switch. It is operated by a push button which engages the end of the sliding door. Fig. 6,841 type is used wherever space limitations will permit. It is operated by a lever and roller which engages with a cam on the sliding door. Either type may be used with wheel, lever or rope operated elevators if a main magnetic contactor be used to control the main line current. The contacts are of single pole double break type.

Terminal Limit Switches.—These switches such as shown in fig. 6,837 *act each time the car approaches the terminal landings, and function to bring the car to rest at these landings in case the operator be careless.*

They may be mounted on the car and operated by cams in the hoistway or vice versa for a traction type elevator. These may also be used on a drum

type elevator although frequently limit switches geared to the elevator machine are used instead.

Overtravel Limit Switches.—These switches shown in fig. 6,839 are always mounted in the hoistway and are operated by cams on the elevator car. They are placed beyond the normal

FIG. 6,837.—Cutler Hammer rotating cam machine limit device for drum type machine. This device is connected with the traveling nut mechanism of the winding drum and opens the control circuits of the magnetic contactors on the elevator controller. The device provides automatic slow down and stop at the terminal landings if the controller has the slow down feature. A centering device must be provided which will return the limit device and the yoke of the traveling unit mechanism to the central position whenever the car moves away from either limit of travel.

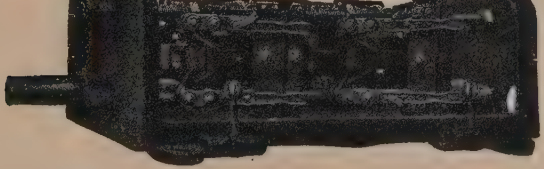


FIG. 6,838.—Cutler Hammer traveling cam machine limit device for full magnetic elevator controllers on winding drum type elevators. The device combines the functions of the ordinary traveling nut device and a machine limit switch. It is geared directly to the shaft of the elevator winding drum. The traveling cam or nut is driven along the length of the threaded shaft as the car moves from one limit of travel to the other. As it reaches either limit the traveling nut trips the double pole snap switches. Two double pole snap switches are provided for each direction of travel. They are the quick break type, adjustable as to position along the threaded shaft and arranged so that they can be locked positively when located. If the elevator controller be provided with the slow down feature, two of the switches may be used for this purpose, one for each direction of travel.

range of car travel, and function *to stop the car in case of the failure of the regular terminal stop limits.*

It is very desirable and the usual practice to arrange the connections to these limits so that the car cannot be backed out of them by manipulating the car switch. This gives an added safety feature as it requires the operator to call the attention of an electrician or someone connected with the maintenance department to the fact that the car ran into the overtravel limits, and have the cause of this overrunning corrected.

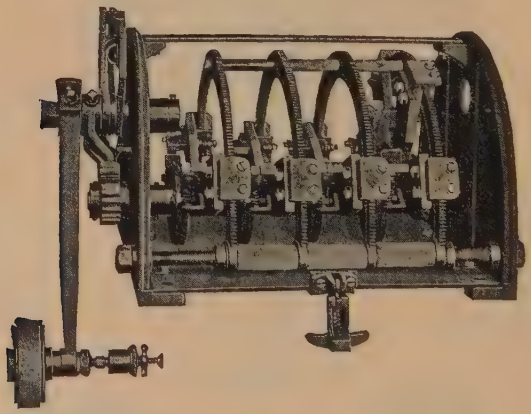


FIG. 6,839.—Westinghouse hoistway or terminal cam type limit switch. ***In construction*** the shaft carries moving cams that operate contacts located on a number of semi-circular supports inside the case. These contacts can be moved to allow adjustment of slow down and stopping position. The main operating shaft is actuated by an arm with a rubber tired roller which engages a cam suitably located in the hatchway. All movements of the switch are extremely quiet.

Slack Cable Switch.—Ordinarily this is used on a drum type elevator *to open the control circuit in case of slack rope caused by the car or counter-weight being caught in the guides.*

It is operated automatically when the ropes slacken. Fig. 6,840 shows the construction. It is sometimes mounted on top of an elevator car of high travel traction elevators where the rope weight is great so that the machine may not entirely lose traction in case of the bottoming of the car.

Door Safety Switches.—These switches (fig. 6,841) in combination with door locks, *prevent the car operating unless all doors are closed and locked.*

The design requirements of these devices are in many cases regulated by safety codes. There are numerous types manufactured and many have little value, so that door locks and switches should be investigated before installing. Some combinations lock the car operating switch in neutral while the door is open. Others interrupt the car control circuit when the door is open.

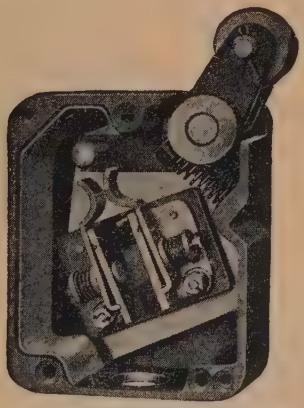


FIG. 6,840.—Cutler Hammer slack rope switch. ***It has*** a latch which, when tripped, causes the contacts to remain open until reset by hand. The switch is used on drum type elevators and on traction elevators over ten or fifteen stories. It opens the main contactor on either semi-magnetic or full magnetic elevator controllers, should the rope become slack either because the car or the counter-weight is caught in the guides. When no slack rope switch is used, considerable rope may become unwound before the operator has an opportunity to shut off the power. The car might then release itself, drop and break the rope.

FIG. 6,841.—Cutler Hammer *a.c.* or *d.c.* door safety switch. ***Designed primarily*** for use in the control circuit of automatic and semi-automatic elevator controllers to prevent starting of the elevator car until all doors are closed. The switches with normally open contacts are used for this service. They are also used as limit switches in the control circuit of *a.c.* or *d.c.* automatic starters on applications such as machine tools, conveyors, etc. The switches are single pole and provide a double break in one side of the control circuit. ***It is operated*** by means of a lever and roller. A cam on the sliding door engages the roller and closes the contacts when the elevator door is closed.

Because the large majority of elevator accidents are due to not using suitable door interlocks, it is advisable to use them even though it decreases the service of the elevator to some extent.

Compensating Cable Switch.—This switch (shown in fig. 6,842) is connected so that *it is opened by the lowering or raising of the compensating rope sheaves in the pit.*

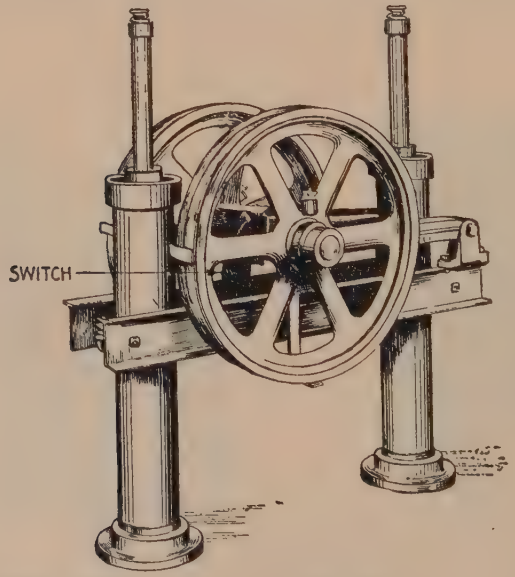


FIG. 6,842.—Elevator compensating rope sheaves with switch.

The switch interrupts the control circuit and stops the car should the sheaves lower to any appreciable extent due to rope stretch. Also, in case of the car or its counter-weight being caught in the guides, the compensating rope sheave will raise and operate the switch to cut off power.

Buffers and Air Cushions.—A buffer is *always required under the car*. For lower speeds a spring alone is used, but for higher speeds a combination of oil dash pot and spring is used (fig. 6,843).

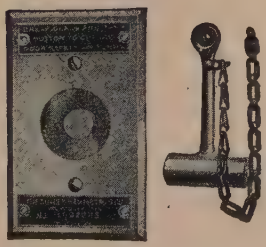
FIG. 6,843.—Oil buffer.

These must provide a retarding effect so that maximum retardation will not exceed 64.4 feet per second per second.

At one time an air cushion was required for certain service in certain localities. This consists of a hoistway practically air tight at the lower end for a certain percentage of the total height. This involved very expensive enclosure construction and while effective in retarding the motion of a falling car it is understood the air cushion has been practically abandoned as unnecessary for safety. Another disadvantage of this scheme is the additional power required to move the car due to air friction.

Protective Devices.—Besides the various safety devices described most elevators are protected against abuse by the following apparatus:

1. Main line service switch and fuses;
2. Circuit breakers and overload relays;



FIGS. 6,844 to 6,846.—Cutler Hammer emergency releases. Fig. 6,844, flush mounted; fig. 6,846, surface mounted. The emergency release is used to short circuit the hoistway door electric contacts in case of emergency such as fire or upon failure of a hoistway door electric contact to make proper contact when the door is closed. Breaking the glass with a small hammer, fig. 6,845, and depressing the normally open contact button short circuits the door electric contacts and allows the elevator to be operated. It is necessary for the operator to hold this button depressed while operating the elevator under emergency conditions. It is therefore necessary to install this release within easy reach from the car switch.

3. Overspeed slow down relay;
4. Phase failure protective relay;
5. Phase reversal protective relay.

Main Line Service Switch and Fuses.—These are mounted in an accessible location in the elevator machine room and are usually enclosed in a metal cabinet, preferably with an externally operated knife switch, and with a mechanical interlock making it necessary to open the knife switch before the cover can be opened to inspect or replace fuses.

Circuit Breakers and Overload Relays.—Circuit breaker protection of individual elevator motors is not very often used inasmuch as the National Electrical Code requires fuse protection of elevator motors even when circuit breakers are used.

Frequently, however, in addition to the service fuses, overload relays are used in order to secure protection against overloading of the elevator itself The overload relays are set below the fuse rating so as to prevent the blowing of fuses.

The overload relays are sometimes made to reset automatically with the return of the operating switch handle to neutral, so that after an overload it is unnecessary to go to the elevator machine room to again place the elevator in operating condition.

Overspeed Slow Down Relay.—Some builders include in their electrical equipment a voltage relay so connected that *an overspeeding of the elevator in either direction will cause the relay to act and thus automatically retard the speed*. This relay is set to act at a speed below that at which the overspeed governor is set.

Phase Failure Protective Relay.—All *a.c.* elevator installations on which the elevator motor may be continuously connected to the lines, such as hand rope and push button controlled elevators, include some form of phase failure protection.

Otherwise, upon the failure of a phase, the motor may be stalled on the single phase condition, and burn out. The protective relay is usually a polyphase, shunt wound relay with a control circuit contact to maintain the control circuit of the elevator controller so long as the phases are all alive. The failure of any phase causes the relay to open the controller circuit and thus disconnect the motor from the supply lines.

Phase Reversal Protective Relay.—Many State electrical codes now require a phase reversal protective relay on all polyphase *a.c.* installations. Frequently the phase failure and phase

FIG. 6,847.—Cutler Hammer phase failure and reversal relay. ***It prevents*** the motor being started if the phases be accidentally reversed. This means that the elevator car cannot be started in a direction opposite to that which the operator expects it to move. The relay will also stop the motor in case of phase failure due to the opening of the supply line at any point, providing the motor is carrying a sufficient load to cause overheating when running single phase. The relay will not operate until the load increases to a harmful point or until an attempt is made to start the motor after stopping. This relay should be arranged to operate through a main magnetic contactor. The principle of operation is similar to that of an induction disc watt meter. A mercury switch opens and closes the control circuit and is so arranged that it makes the relay very sensitive to phase unbalancing, and yet the entire construction is rugged and dependable. Standard relays can be used without modification on either two or three phase circuits. No transformers are required on any circuit up to and including 550 volts. A change of voltage or frequency merely means the change of two small coils.

reversal relays are combined in one device. The reversal of phases immediately opens the controller circuit and prevents the elevator motor being connected to the lines until the relation of the phases is corrected.

TEST QUESTIONS

1. *What are terminal limit switches used for?*
2. *Describe the overtravel limit switches.*
3. *What is a slack cable switch and how does it operate?*
4. *Describe the construction of door safety switches.*
5. *Of what does a compensating cable switch consist?*
6. *What is the operation of buffers and air cushions?*
7. *How are the main line service switch and fuses mounted?*
8. *Are circuit breakers and overload relays often used?*
9. *What is an overspeed slow down relay?*
10. *When should a phase failure protective relay be used?*
11. *Are phase reversal protective relays necessary?*

CHAPTER 158A

Elevator Maintenance

Elevator maintenance may be defined as the *work of caring for the elevator plant or equipment* in such a manner that all parts of the system will function properly and continue to do so year in and year out without undue interruption of service.

There are three methods generally employed to obtain elevator maintenance. They are:

1. To contract for the entire maintenance program with an elevator company;
2. To make an arrangement with an elevator company to send out men for inspection and service at regular time intervals;
3. To employ expert maintenance men in the building proper and purchase repair parts only as the need arises.

In the first case the elevator company assumes full responsibility for everything, such as supplies, repairs, cable replacement, trouble calls, etc.—night and day.

The second method means keeping an elevator man in constant attendance, and is obviously one which may vary through a considerable range according to what proportion of work is to be done by the elevator company under their service contract.

The third method implies the employment of expert service mechanics, the personnel depending on the number of cars in use and to some extent on the kind of elevator equipment.

No attempt will be made here to discuss the relative merits of these three methods, because generally each case will be governed by its own merit. Many owners, however, prefer the third method because it enables the owner to know exactly in advance what the elevator item on the year's maintenance budget will be; second, because they are assured of expert upkeep and adjustment, and third, because they are in effect insured against unusual repair bills.

Elevator Tests.—On the completion of an installation of electric elevators, tests are made to see that all parts of the equipment are in good working order; that the speed and load requirements have been met, and that the safety equipment can be relied upon satisfactorily to operate as and when required. The principal points that receive attention are outlined as follows:

A careful inspection of all details of the elevator plant should be made to see that the contract has been executed in a thoroughly satisfactory and workmanlike manner. Points to note are conduit and cable; main switches and fuses; control panel; leads from control panel to motor, etc.; machine bed; foundation bolts; bed plate level in both directions; that all bolts and nuts are tight; gears (if used) and bearings supplied with oil; rope fastenings and groove conditions; floor leveling device; guide rails; fixings and joints; car; car operating device; signaling system; landing doors, electrical interlocks and wiring for same; counterweights and rope connections, etc.

Weights equivalent to the rated car capacity is placed in the car and speed checked, allowing for acceleration and retardation. Full speed checked on both upward and downward journeys should not vary by more than 15%.

Limit on tests are made with a load of 150 pounds (operator) only in the car. The figure obtained for speeds with minimum and maximum loads in the car are then compared.

Acceleration and retardation are checked with minimum and maximum loads in the car to see that it is smooth and even under both conditions and in both directions of travel.

The test required to prove the car safety gear and the guide grips will vary with the type installed.

Ride in the car and observe if there is any objectionable side or end play, due to incorrectly adjusted guide shoes.

With full load in the car, run the car at full speed into the limit switches, both at the top and at the bottom of the shaft. Then cut out the limit switches and repeat the test with the ultimate limit or overtravel switches only.

With full load in the car, observe the starting kick and running current and check this with the rating plate on the motor. Using a dead beat ammeter, allow 5% kick or final rush. The accelerating current should not exceed 50% in normal cases on a direct current motor and 250% on an alternating current motor.

Gradually reduce the load in the car until the current on the up trip is equal to the current on the down trip. At this point the load in the car should normally equal 40% of the rated car capacity.

Check the operation of all safety interlocks fitted to landing floors.

Run the car for a mile at capacity load and observe acceleration, retardation, and also any excessive noise or vibration. Immediately afterwards switch off the current and observe the temperature of all bearings, gears, motors, controllers, brakes, resistances, etc.

Take insulation tests of motion controllers and wiring and localize cause of low readings (if any).

Carefully check the operation of the signaling equipment.

The *maintenance* engineer should understand all of the foregoing thoroughly, and he should have spare parts for all points of the elevator. A card of "Working Instructions" should be securely fixed in the motor room or other convenient place, bearing the name and telephone number of the nearest Elevator Service Depot.

Character of Inspection.—The character of service rendered in most installations is a weekly examination of the entire plant, except signal devices, including oiling and cleaning the machine, motor and controller, greasing and oiling bearings and guides, making necessary minor adjustments and furnishing call-back service during regular time. This service also includes the furnishing of small parts for replacements, such as

copper and carbon contacts, insulation, springs, braids, motor brushes; also oil and grease.

Where high-speed elevators are operating under severe service requirements, it is often necessary to have examinations and adjustments made daily. The examinations may be made semi-monthly, where the service is intermittent.

A well-organized scientific inspection embracing the following features with the object of constantly maintaining an elevator at the highest point of efficiency and safety should be organized. This includes:

1. An expert regular examination of the apparatus;
2. The thorough lubrication of the machinery with the best lubricants;
3. A regular adjustment of the moving parts;
4. The renewal of all wearing parts prior to any chance of their failing to function;
5. The careful examination of cables and their renewal before the probability of breakage;
6. Renewal or repair of all other parts of the elveator whenever such is required.

This service, which numbers its users by the thousands, acts as a preventative for troubles of all kinds, and provides the elevator owner with many advantages, such as:

1. He can determine beforehand a reasonably fixed monthly cost for maintaining his elevators. As this is in the nature of cost insurance, it enables him to budget accurately;
2. He can offer to the passengers of his elevators (the public) the maximum of safety, together with the absence of those annoying delays due to interruption in the service;

3. It materially prolongs the life of the apparatus and prevents later costly repairs or even complete renewals.

This service should be handled by a special expert examination that functions in the interest of elevator users.

A regular system of inspection is one of the essentials to rendering good elevator service and keeping the equipments in a safe operating condition.

Where to begin inspecting elevator equipment is a question that engineers are not agreed upon. Where some will start with the motor, others will begin with the hoistway doors or start on hoisting ropes. It makes little difference where the work is started so long as it is thorough.

Starting at the motor, the lubrication, the condition of the bearings, the brushes and commutator, and any evidence of winding trouble are noted. On worm-gear machines, the position of the armature or rotor between the bearings should be checked. When the thrust bearings wear, they may allow the thrust of the worm shaft to be transferred to the motor bearing. The latter are not designed to take the thrust and they may overheat if subjected to it.

Next to the motor comes the brake. To a degree, on its adjustment and condition depends the safety of the passengers in the car. If it is not working properly, the operator will make many false stops. These not only impair the elevator service, but also increase the power consumption per car mile. Therefore, safety, service and economy dictate that the brake should be properly adjusted.

The control equipment may be given a third place on the program. All contacts should be examined to ascertain that they are functioning properly. There are many things that can happen on a controller, such as contacts out of adjustment, shunts and contacts loose or broken, all of which should be located and repaired before they cause trouble.

While in the motor room the elevator machine should be checked. If the machine is of the gear type, check is made of the height of the oil in the gear case. Its level should be at the center line of the worm. The worm should not have excessive thrust. Before this condition exists, the thrust bearings should be adjusted or renewed. Lost motion on the drum is usually due to one or more of the following reasons: worn thrust bearings, worn gear teeth, loose or worn bearings and the gear loose on the spider. All the causes should be checked and corrected if found to exist.

The only remedy for a badly worn gear is to replace it. The drum and sheaves should be checked for looseness on their shafts. Their rims and spokes should be examined and hammer tested for cracks.

The ropes on the drum and sheaves should be given attention to see that they lead off and on the drum without bending. Where deflecting sheaves are used on drum machines, they should move freely on their shafts or they will cause the ropes to rub on the side of the grooves and result in unnecessary wear.

When inspecting the governor, the flyballs are lifted until the rope gripping jaws are released, noting if the auxiliary switch functions properly. The governor should be reset; care being taken to see that the auxiliary switches are in their correct positions. The governor should be kept clean and all moving parts lubricated.

After the equipment in the motor room has been inspected, the hoistway and the car should be given attention. The hoistway doors and their locks should be carefully gone over. Where the doors are held closed by ordinary latches, the inspector should try to open each door without lifting its latch. It should also be noted if the doors latch readily when they are closed.

When the doors have interlocks, the inspector should try to start the car at each landing with the door partly open. If an automatic door closer is used, it should be noted how far the doors are open when the interlock closes and the car can be started. If the doors are power-operated, all parts of the operating mechanism must be examined carefully to see that it is in proper working order.

The safety devices under the car should be examined by the inspector, getting down into the pit and having the operator lower the car to expose all parts. The guide shoes should be replaced before they are worn sufficiently to allow the safety shoes to come in contact with the rails. The safety devices should be operated by hand to insure that they are in good working condition, and that all moving parts are well lubricated. While the inspector is in the pit he should examine the oil buffers to see that they contain sufficient oil.

When the car has compensating ropes, they should be examined from the pit. The best way to do this is first to examine the connections at the car to see that they are secure and that there are no broken wires at the sockets. Then, while the operator raises the car about three feet at a time, the inspector examines the ropes for broken wires or other objectionable conditions. When the car has reached the top of the hoistway, if the counterweights come down far enough, the rope's connections to their bottom can be examined, as can the lower guide shoes. If this inspection cannot be made from here, it can be taken care of from the top of the car. The length

of the ropes should be noted. With the car at the top landing, there should be one or two feet clearance before the counterweights will land on the buffer in the pit.

The position of the governor rope and the compensating rope sheaves should be noted to see that they are in a position to function properly and have sufficient clearance under them.

The hoisting ropes and governor ropes can best be inspected from the top of the car, with an inspector on top, the operator running the car to a position in the hoistway where the counterweights can be reached. These can be inspected first, and then as the operator raises the car, about two feet at a time, the inspector should carefully examine the ropes. The car guide shoes, limit switches and other equipment that may be on top of the car and in the hoistway should be examined as part of the rope-inspecting job.

In the car, the chief objects of attention are the car switch and the gate. The safety switch should be opened and the car switch moved to the *on* position to see if the potential switch drops out and cuts the power off the motor, as it should. The cover is next removed from the car switch and the contacts inspected to see if they are in good condition and function correctly. If the gate has a contact to prevent the car's being started with it open, a search should be made for the cause of the short circuit on the contact circuit.

The equipment to be inspected and the method of doing it will vary with the type of machine, but the foregoing suggests a system that covers the most important features of any installation. In the maintenance of elevators, like with any other equipment, keeping it clean is about 75% of the job. If equipment is thoroughly cleaned every week or two most of the minor defects will be detected.

It is important to remove all kinks from the governor and safety-operating rope; also to examine the governor rope to determine if it has been damaged sufficiently to require the installation of a new rope.

If the elevator is equipped with a roll-type safety, the rollers in the safety jaws should be inspected after an application of the safety, before the elevator is again started, to make sure that the rollers are in their correct position for the next application.

After any car safety application and before the car is again placed in operation, a thorough inspection should be made of the governor, tension frame and all parts of the safety mechanism.

On drum machines it is very important that all slack in the hoisting ropes be taken up before the safety is released; otherwise the car will drop until the slack is taken up and the sudden stop may snap the ropes. The slack is taken up by slowly turning over the machine until the ropes are taut. Be sure that the ropes go back on the drum in the proper grooves.

Some safe-lift drum-type machines are equipped with back-gears, and are provided with additional counterweights. On single-wrap traction and gearless traction safe lift elevators, there is provided additional counterweight and a throw-over switch on the controller to short circuit a portion of the starting resistance. On some micro-drive gearless elevators a throw-over switch is provided to permit continuous operation at slow speed by means of the leveling motion. Before attempting to carry safes or other heavy material on the car, the extra counterweight (where provided) should be added, and the machine arranged for safe-lift operation in increasing the brake spring tension on both brakes.

All safe-lift elevators are also equipped with a locking bar on each end of the safety frame. When these bars are thrown out in their extreme position, they land on clips on the guide rail at each floor. This locking device is operated by a wrench through the corner of the car platform.

Before operating the locking bars, move the car platform a few inches above the designated floor, and by means of the socket wrench throw the bars out in their extreme position. Then lower the car very slowly until the platform comes to rest securely on the clips.

Be sure that the bars have a full bearing on the clips. After loading the safe on the car, raise the car a few inches, and by means of the socket wrench move the bars to their extreme position. Be sure that the bars are clean of the clips. Under no circumstances attempt to load a safe or other heavy object on the elevator platform without landing the car platform on the clips as above noted, and after loading the platform do not attempt to lower or raise the load, except as noted, until the bars have been withdrawn and are entirely clear of the clips.

The largest item of maintenance cost of a modern high speed elevator is the ropes. Operating conditions have a marked influence on rope life. Some of these are controllable, others are not. In a given installation unequal loading is probably one of the chief causes of short rope life. On a traction machine this may develop from unequal stretch of the rope or unequal tread diameter, or the grooves in the traction sheave will cause one rope to travel faster than the other, producing a slippage and unequal loading.

Devices such as commutator stones and grinders, commutator undercutting tools and hand motor-driven blowers have a place in the maintenance of the electric equipment on elevators just as they have on electrical machinery for industrial purposes.

Once each year, or every two years, depending on conditions, the motor windings should be given a thorough cleaning and a coat of air drying insulation varnish.

Lubricating the guide rails by hand has always been not only an unpleasant job, but also an unsatisfactory way of doing work. When they are first greased there is too much lubricant on them, and before they are greased again they are frequently dry. Several automatic guide rail lubricators have been developed that reduce the job to filling a reservoir with oil or grease every month, or at longer intervals. These devices relieve the maintenance man of an objectionable and dangerous job, insures the rails getting a continuous supply of lubricant, and the car does not have to be taken out of service to grease rails.

Metering devices are valuable tools in a proper operating and maintenance program. A megohm meter should be used to check the electrical machinery insulation. A watt-hour meter on each elevator in connection with a mileage recorder are used to obtain a record of power consumption per car mile. They show the daily mileage of each car and rope life. When stop recorders or counters are used on car switch-controlled elevators, their record combined with those of the mileage recorders will provide a means of obtaining the stops per car mile and per trip. This is valuable in checking up on operators and the brake adjustment.

If an operator is making an excessive number of stops, it shows that many of them are false, either through the fault of the operator or because of an improperly adjusted brake. A study of records of the number of stops per car mile and of power consumption shows the power per car mile invariably increases as the number of stops increase.

Modern elevator equipment has been brought to such a high degree of development that its expected life can be assumed to be that of the building. However, there are many conditions in the older type of buildings where changes can be made that will improve elevator service. Even modern elevators may be made more efficient and the service improved by changes in the auxiliary equipment. The old signal system may be replaced by one that is more effective; an automatic scheduling system may be installed to dispatch the cars instead of having this done by the starter; manually operated doors may be equipped with automatic closers or they may be power-operated and an improvement in the service obtained.

In the older types of buildings many changes have been made by installing complete elevator equipment. Frequently old controllers are replaced. Where the machines are operated from *a.c.* it is often possible to replace the old motor by a new one and reduce the power consumption by one-half, improve the elevator service and reduce the maintenance cost, thereby effecting considerable saving.

Servicing Elevators

The following schedule in servicing will greatly facilitate the work of servicing, as follows:

Operation No. 1.—Examine main line switch serving elevator to insure that switch blades are working properly and that proper size fuses are used. Also see that proper fuses are used on controller and that they are making proper contact in holders.

Operation No. 2.—Examine and adjust all moving parts of the controller. Clean or renew contacts where needed and check up to see if all connections on binding posts are secure. Hinge pins and other parts which require it should be lubricated.

All connections to motor should be examined to insure that they are secure and in proper place. If of the slip ring or commutator type the brushes, brush holders, commutator, slip rings and other parts having to do with the motor's operation should be gone over carefully to insure that they are in proper condition and adjustment.

In the case of *a.c.* motor, either for the elevator proper or the M.G. set, the air gap should be checked to insure that it is correct. All motor windings, irrespective of the type, should be gone over carefully to insure that they are free from oil and dirt and other foreign matter which might result in damaging such parts.

The bearings, all motors, generators, etc., should be gone over very carefully to insure that there is sufficient oil to properly lubricate them and that the oil is of the proper quality. Such bearings should be drained off at proper intervals and fresh oil supplied.

Operation No. 3.—Examine brake to insure that connections to magnet coils or motor are secure and that all adjustments are correct for the service, especially that the brake shoes are adjusted as close to the pulley as conditions will permit. All pins and other moving parts should be lubricated and a careful examination should be made of all such parts to insure that cotter pins or any other method which is used to hold such parts are in proper place.

In case of an *a.c.* brake, the proper amount and quality of oil should be kept in the magnet case. This should be looked after at each examination.

In the case of an *a.c.* motor-operated brake, be sure that the dash pot adjustment is correct.

Operation No. 4.—The lubrication of the worm and gear should be such as to insure that the latter carries oil over the top. Usually keeping the worm chamber two-thirds full will accomplish this. The worm-gear chamber should be drained out at proper intervals, depending on the service of the elevator and fresh oil supplied.

The lubrication and condition of all drum or driving sheave shaft bearings should be checked carefully, also if there is excessive play in the worm or other shafts, the stuffing box gland should be adjusted to insure that an excessive amount of oil will not leak out.

Operation No. 5.—Examine carefully the safety governor to insure that all parts are in proper condition and well lubricated. This is very important.

Operation No. 6.—Clean machine, governor, controller, motor and all other parts. Especially, see that the machine room is kept free from oil cans, dirty waste and all other rubbish. Oily or dirty waste should in no case be left exposed or thrown where it might cause damage from fire. It is possible for oil-soaked waste to cause spontaneous combustion. For this reason it should be kept in a metal container or disposed of in such a way as to avoid any possible damage from this action.

Operation No. 7.—Examine carefully all ropes to insure that there are no broken wires, damaged places or other conditions which might result in their breakage and cause a serious accident. Ropes as a rule give some warning of their condition before it is necessary to renew them. It is possible for wire ropes to break up internally if not properly lubricated. For this reason all old ropes should be lubricated.

When ropes are manufactured the center core is saturated with a lubricating compound. When the rope is put into service this lubrication penetrates the wires and it will keep them lubricated for some time. However, this lubrication is gradually used up and even though the rope appears to be properly lubricated on the outside, it is possible that the fibre core in the center of the rope and the wires around it are dry and cutting. The service of the elevator and the condition of the rope itself will determine the amount of lubrication required.

For basement machine, all overhead sheave bearings, shafts and sheave grooves should be gone over carefully and the former properly lubricated.

The importance of keeping overhead sheave bearings or in fact slow moving journals of all kinds properly lubricated is very often overlooked.

The fact that there is grease in the chamber provided in the bearing does not insure that the journal is lubricated. Grease will become hard if allowed indefinitely to remain in grease cups or other reservoirs which have been provided for lubrication. It is necessary from time to time to clean out the old grease, also the oil holes leading to the journals, to insure that the fresh oil which is being supplied will do its work. Lack of lubrication at such points will result in unnecessary friction and excessive wear.

Operation No. 8.—Examine main and counterweight rails to see that all brackets and rail clips are tight; also that rails are properly lubricated. Check up on car shoes for wear and adjustment and see if they are properly secured to crosshead and safety plank. Where compensating chains are used, examine chains and hitches on outriggers and final hitches on safety plant and hitches on bottom of counterweight frame to see if there is any indication of their breaking loose.

If wire ropes are used for compensation, see that they are properly adjusted for tension and hitches under car, and that bottom of counterweight frame is secure. Also check for wearing. Examine compensating sheave bearings for condition and lubrication; also see that frame is free in guides and that slack cable switch for same is working properly. Examine governor tension sheave and make sure that it is free and well lubricated. If oil buffers are used under car and counterweight see that they are in proper working order and oil chambers are kept filled to the proper level with the correct oil.

Operation No. 9.—Examine safety devices. If roll safety is used, make sure that tripping rods are set even so that the steel rollers in safety shoes will rise at the same time; otherwise if one engages before the other, the car will pawl out of level and may cause serious damage. See that all moving parts of safety devices are free and well lubricated.

If wedge clamp safety is used, examine releasing carrier and lead sheaves for safety rope and make sure that there is no undue friction on sheaves; also that they are properly lubricated. Examine safety drum rope to see that there are no kinks on safety drum; also that cable is set properly in grooves of safety drum. Make sure that safety drum is free and all bearings and moving parts are well lubricated. If flexible guide clamp safety is used, examine lifting rods for safety rollers in safety shoes and see that they lift even, so that car platform will be level when safety is applied; that safety releasing spring is properly set; that equalizing spring is properly set to give proper clearance to jaws on rails. Also, that nuts for releasing safety jaws are backed free from jaws after safety is released. Examine all

moving parts of safety and see that they are properly adjusted and well lubricated. Examine all bolts in carframe and counterweight frame and tie rods for counterweights. If car emergency safety device is used, see that all the moving parts are kept free and well lubricated. This operation is very important.

Operation No. 10.—Examine traveling cables to center junction boxes and under car platform to see if steel supporting wires are holding. Examine traveling cables throughout shaft to see if outside coverings are wearing off; also, if traveling cables are fouling anywhere in shaft. Examine top and bottom final shaftway limit switches and make sure that they operate properly. If the different switches for the *up* and *down* direction of car travel are mounted in shaft or on crosshead of car, see that contacts for these different switches are making properly; also that moving parts of these switches are lubricated where needed.

See that cams for these switches are secure either to car or rails. Check the *up* and *down* direction of car travel from car switch to see if automatic device operates properly; also, see if car switch contacts are making properly, and contacts and other moving parts of switch are well lubricated; renew contacts in all switches where needed. Examine safety switch in car and see that contacts are making properly; also, examine safety plank switch under platform of car.

Examine door contacts and gate contacts, adjusting or renewing parts where necessary; also, examine emergency cutout switches for door and gate contacts. Examine light switch and fixture in car and see that they are in proper working order. Examine and adjust door-closers if used and included in service contract.

Operation No. 11.—Clean top and inside of car under platform, main and counterweight rails and bracks in shaft, counterweight frame and pit of elevator shaft, ledges, sills and other hatch projections.

Operation No. 12.—Examiner should have his report signed by someone in authority at the building. Also make out report for any recommendations on regular form, not on his report sheet.

General.—The foregoing system can be applied to all types of elevators with the following exceptions:

Hand Rope Operation.—Examine operating rope for wear; also, see that top and bottom terminal stop balls are properly set; that stop balls on back stop in shaft are set to make ahead

of steps on controller or flyer sheave. If drum-type elevator, see that machine automatic device is set for top and bottom terminal landings, also that slack cable switch and parts are working properly.

Push-Button Operation.—Examine contacts on floor controller, adjusting and renewing where necessary. Examine chain and sprockets on floor controller to see that they are in proper working order. See that all moving parts are lubricated where needed. If single wrap traction, see that proper tension is kept on the machine friction drive sprocket to properly operate floor controller; see that limit switch mounted on car or in shaft that controls corrector mounted on floor controller is working properly; be sure that terminal reset lugs are properly set on main floor controller gear; also that friction stud chain and sprocket and gears are in proper working order and moving parts are lubricated where needed.

Check up on floor landings to see if platform is stopping level to floors, resetting where necessary.

Examine door locks and contacts and cam magnet on motor that operates retiring cam for door locks, making necessary adjustments where needed or renewing contacts if needed.

Examine car operating buttons, hall buttons, emergency stop button, emergency alarm button and bell, light switch and fixture in car to see that they are all in working order, renewing parts when needed.

If movable platform is used, see that platform is free from all undue friction and all moving parts are well lubricated; also that king pin bolt is secure and contacts on platform switch are secure and making properly. Proper action should be checked very carefully.

Examine shaft enclosure doors and house locks to see that they are in proper working order. If dual control is used, see that throw-over switch or motor-operated remote throw-over switch mounted on controller are working properly.

If micro is used, see that motor-operated leveling switch is kept properly adjusted; also contacts in same. Keep chain and friction device properly

adjusted and all moving parts well lubricated. Check up on cams at each floor and see if they are properly set and secure; also check up on micro leveling device to see that car platform stops level to floor landings.

Micro Machine.—Examine gear shaft bearings in regard to lost motion in same; also end play on worm shaft. See that worm shaft is kept two-thirds flooded with oil and that oil wells for motor bearings are kept filled to the proper level.

Unit-Multi-Voltage Control.—Examine and adjust contacts on controller panel of motor generator set, renewing contacts where necessary; also check up on all connections on panel to see that they are secure to binding posts.

If *d.c.* examine armatures and fields of motor generator sets and make sure all connections to them are secure and that commutators are kept clean and brushes are properly adjusted; check to see that oil wells of motor and generator are kept full to the proper level; also see that contacts on governor switch are working properly if switch is used on set.

When *a.c.* is used for the power supply, examine connections to stator of squirrel cage induction motor and see that they are secure; verify that rotor connections are secure; also see that connections to generator and exciter armatures and fields are secured and commutators are kept clean and brushes properly adjusted and oil wells for bearings kept filled to the proper level.

If main or auxiliary motor micro is used, see that motor-operated leveling switch is kept properly adjusted; also that contacts are making properly. Keep chain and friction device properly adjusted and all moving parts well lubricated. Check up on cams at each floor and see if they are properly set and secured. Also check up on micro leveling device to prove that car platform stops level to floor landings.

If auxiliary motor micro is used, examine main revolving brake and see that adjustments to it are properly made and all moving parts are well lubricated; make sure that brake for micro machine is properly adjusted and moving parts are lubricated; examine gear bearing in regard to lost motion on same; also check up end play on worm shafts. See that worm shaft is kept two-thirds flooded with oil. Examine motor bearings and see that oil is kept to proper level in oil wells.

Multi-Voltage Signal Control.—Examine and adjust contacts on master signal controller board and see that latching magnets are working properly and that all connections on front and back of controller are secure to binding posts.

Examine selector machine and verify that traveling crosshead and revolving worm screw are free and well lubricated and that all contact brushes and contact plates are making properly; that all connections to selector are secure to their binding posts; also see that pawl magnet stops are properly set.

Examine selector sheaves and shaft bearings and see that they are properly lubricated; examine steel tapes from these sheaves to top of car and to underside of platform; examine tape tension sheave in pit of shaft and see that it is free and well lubricated; that sprockets on end of tape sheave shaft and shaft to selector are secure; also sprocket chain. The brush magnet on crosshead of selector must be properly adjusted and contacts for it must make properly.

Examine top and bottom of final shaftway limit switches and make sure that they operate properly. Examine automatic switch mounted on crosshead of car and see that it operates properly and top and bottom stationary cams for same are set properly; be certain that small double series field motor used for reversing purposes is free and well lubricated and that all the contacts make properly.

Examine car-operating box and see that the different stopping buttons are working properly; also the starting switch, slow speed switch, non-stop safety switch, micro switch, emergency cutout reversal switch, light switch and key switch for starting and stopping the motor generator set. Examine safety plank switch mounted under car platform and see that contacts are making properly.

Examine door contacts, adjusting or renewing contacts where necessary, also gate contacts. Examine and adjust automatic door openers and closers to see that they work properly; see that light fixture is in proper working order. Examine the *up* and *down* hall signal lanterns and see that they are in proper working order. Inspect *up* and *down* buttons, making necessary adjustments where needed, also renewing any contacts if necessary.

TEST QUESTIONS

1. *What are the three methods generally employed to obtain elevator maintenance?*

2. *What are the principal points to be checked upon the completion of an elevator installation?*

3. *In elevator engineering, what is meant by the term "car mile"?*

4. *What is the largest item of maintenance cost in modern high speed elevators?*

5. *How often should the elevator motor windings be cleaned, and a coat of air drying insulation varnish applied?*

6. *Enumerate the metering devices and their function as used in elevator tests.*

7. *What is the method used in obtaining a record of power consumption per car mile?*

8. *What is the purpose of the safety governor and what should be observed with reference to its maintenance?*

9. *What is the proper sequence in examination of elevator roping?*

10. *What should be done to prevent fire in the elevator control room?*

11. *What is the purpose of lubricating ropes in an elevator installation?*

12. *What should be observed with respect to the micro machine when inspecting an elevator so equipped?*

13. *What is the proper sequence of procedure when inspecting elevator doors?*

14. *What is generally understood by the term elevator safeties?*

CHAPTER 159

Gas and Electric Hoists

A hoist represents a class of machinery possessing wide utilities, for besides general hoisting work, there are other special duties to which it is adapted. Its development has been brought about chiefly by builders of this class of machinery being brought into touch with contractors, miners, bridge erectors, freight handlers on ships, docks, etc., resulting in a machine well adapted to the requirements.

There are a number of terms relating to hoists which are here given and which will be found helpful in understanding the subject.

Aerial dump.—An improved type of conveyor having low sides, and open at one end. The form facilitates the handling of material by a cableway.

Boom fall rope.—The rope which operates the vertical movement of the boom of a derrick.

Boom swinging gear.—A device for operating a radial or boom swinging derrick. It consists of a drum, or two spools on which the boom swinging ropes are simultaneously wound and unwound.

Bull wheel.—On radial derricks, a large wheel at the base of the derrick consisting of a circular flange made of structural T iron to which the boom swinging ropes are attached.

Clam shell grab.—A term used to describe a form of bucket used in dredging, excavating, and conveying loose material such as coke, sand, etc.

Cone.—An iron cone shaped cap used in logging operations to assist the log to pass over obstacles when skidding.

Derrick swinging ropes.—The two ropes which control the radial position of the derrick, or by means of which the derrick is made to revolve.

Differential brakes.—Band brakes, in which both ends of the band are pivoted to the rocker but at different distances from the center of the load held, tending to turn the rocker in the direction to apply the brake.

Dock wheels.—Small cast iron wheels fitted to hoists and forming a running gear, for use on docks or places where it is necessary to move the hoist frequently.

Drum.—A revolving flanged cylinder, to which the hoisting rope is attached.

Drum spring.—A spiral steel spring which pushes the drum out of contact with the friction woods when the friction pressure is released by the friction lever.

Dumping block.—A form of block consisting of a small and large wheel. A piece of chain inserted in the hoisting rope at the right point causes the small wheel to revolve which raises the back end of the skip, and allows the load to *dump*.

Foot brake.—A band brake for controlling the movement of the drum.

Fixed drum.—A type of drum in use where only single loads have to be handled.

Friction lever latch.—A device consisting of a thumb latch and detent, engaging with serrated teeth in a quadrant, by which the lever is held in any desired position.

Friction nut.—A large nut at the end of the drum shaft and attached to the side stand. The friction lever screw works in this nut and communicates motion to the friction pin.

Friction pin.—A steel pin which communicates lateral motion from the friction screw to the drum, bringing the latter into contact with the friction woods.

Friction screw.—A powerful steel screw located near the end of the drum shaft and operated by the friction lever. It communicates motion to the friction pin.

Friction woods.—A concentric layer of wooden blocks attached to the gear wheel, at the end of the drum, and furnishing the frictional contact between the two.

Guard bands.—Protecting wrought iron bands fitted over the gear wheels to prevent the rope or any obstruction getting in the teeth of the gear.

Locking levers.—On double friction drum engines designed for handling a boom derrick. When the friction lever is moved, for the purpose of throwing the drum into gear, the pin on the end of the friction lever presses against the curved part of the oscillating lever and releases the foot brake. When the lever is moved back, the operator places his foot on the foot brake for a moment, and the oscillating lever drops back into its original position, thereby locking the brake on the drum.

Loose drum.—A drum, free to revolve on its shaft, and which is thrown in or out of engagement with the driving shaft by means of a clutch.

Main hoist rope.—The rope which raises or lowers the load.

Operating levers.—Devices for operating the brake, friction, etc., in hoisting. They are usually assembled together and conveniently located for the engineer.

Orange peel grab.—A term used to describe a dredging device which when opened assumes the shape of an orange peel divided into four parts.

Outhaul rope.—In logging operations, an auxiliary rope, worked by a separate drum. It is used to carry the skidding rope out into the woods, which, by former methods had to be done with mules or men.

Post brakes.—A type of brake in use on reversible, mining, and hauling engines.

Radial ribs.—Cooling ribs placed outside of the drum friction surfaces to assist in carrying off the heat generated.

Shrouded ratchet ring.—A ring having ratchet teeth around its circumference and bolted to the drum flange. The outer edge of the ring is provided with a shrouded flange, thereby preventing the teeth being broken by the pawl, or the pawl slipping off.

Side stands.—Supporting frames usually of T shaped section and designed to carry both the drum and crank shaft bearings.

Skip.—An iron box with a bale holding from one to ten tons of ore or rock; used for hoisting and running between guides, or in inclined shafts to run on a track.

Sluing drums.—Two pony drums located on one shaft, and especially adapted for the operation of radial or swinging boom derricks.

Snaking and loading machine.—In logging, a hoist with rigging so arranged that the operations of hauling and loading may be carried on from separate booms independently and at the same time.

Stiff leg derrick.—A form of derrick fitted with wooden braces instead of guy ropes for support.

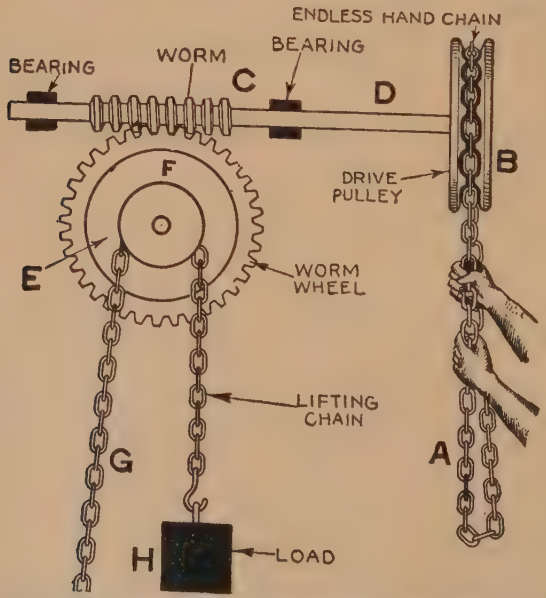


FIG. 6,848.—Elementary worm gear hoist. The hand chain A, is used for rotating the drive pulley B, which is connected to the worm by a shaft. The worm meshes with the worm wheel E, whose shaft is attached to a pulley over which passes the lifting chain G. The pulley F, has pockets for receiving the chain links so that the chain cannot slip in lifting the load H.

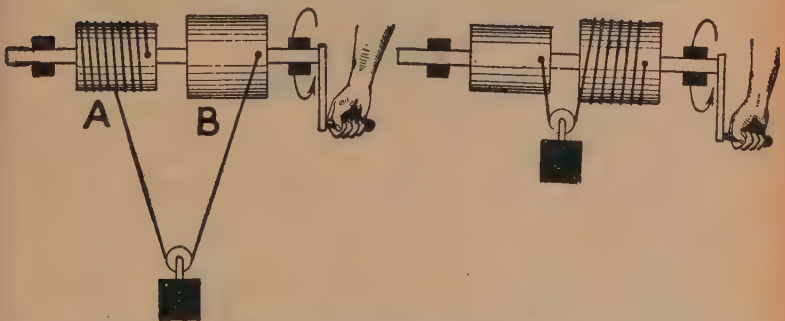
Tail sheave.—A pulley used in the "pull boat system" of logging.

Winch heads.—A short hoisting drum or spool having curved flanges, and attached to an extension of the drum shaft.

Classes of Hoists.—The great variety of hoisting work, calls for different kinds of engine designed to meet special conditions. They may be classified in several ways:

1. With respect to the power, as
   - *a*. "Gas";
   - *b*. Electric.

2. With respect to the transmission of power; as,
   - *a*. Direct drive;
   - *b*. Geared transmission.



FIGS. 6,849 and 6,850.—Chinese windlass illustrating the principle of the differential hoist. *It consists of* two drums, A and B, (one a little larger than the other) connected to a shaft and having the ends of a lifting cable attached to the drum as shown, so that in turning the crank the cable will simultaneously unwind on one drum and wind on the other. Fig. 6,849 shows the beginning of the lifting operation. As the crane is turned clockwise the cable winds on B, and unwinds on A, and since B, is larger in diameter, the length of cable between the two drums and load is gradually taken up, thus lifting the load. Evidently by making the difference in diameter of the two drums very small an extremely large leverage is obtained thus enabling very heavy weights to be lifted with little effort. The load will remain suspended at any point, *because the difference in the diameter of the two drums is too small to overbalance the friction of the parts*. Fig. 6,850 shows the end of the lifting operation.

3. With respect to the drum arrangement; as,
   - *a*. Fixed drum;
   - *b*. Loose drum;
   - *c*. Single drum;
   - *d*. Multi-drum;
   - *e*. Cone drum.

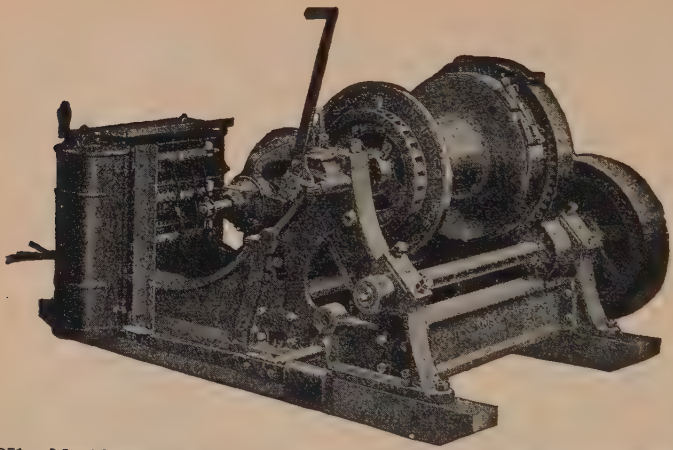


FIG. 6,851.—Mead-Morrison single drum ***electric hoist.*** This type is particularly adapted for hauling cars or hoisting elevators. It is found also on docks for hoisting and hauling of general cargo into warehouses, and in general building construction. It is equipped with slip ring motor and drum controller, but for many requirements the less expensive half high torque motor which has no controller is as well suited.

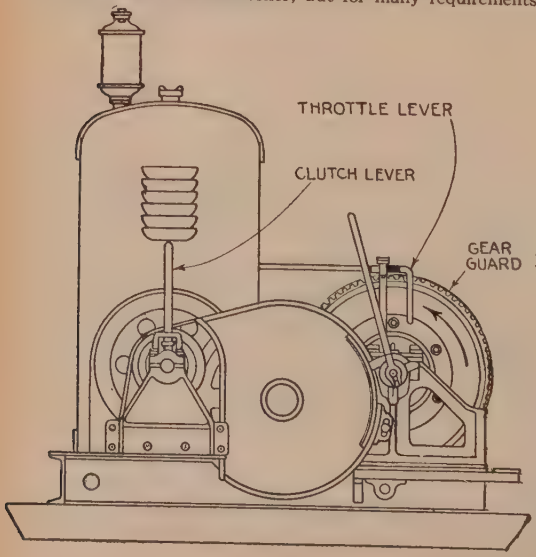


FIG. 6,852.—Novo gas engine driven hoist powered with four cylinder engine, radiator cooled. The engine has two fly-wheels, which approximates steam engine flexibility. With an engine equipped with two flywheels, when handling a concrete tower elevator, the engine may be throttled and the load will float to the proper stopping point without stalling the engine. This makes faster and more efficient hoisting.

4. With respect to the conditions of service; as,

a. General service;
b. Coal hoisting;
c. Boom swinging,
etc.

The Simple Hoist.—In its simplest form a hoist consists of a hoisting drum, having a friction brake and geared to a motor as in fig. 6,851 or to a gas engine, as in fig. 6,852, the assembly being mounted on one base.

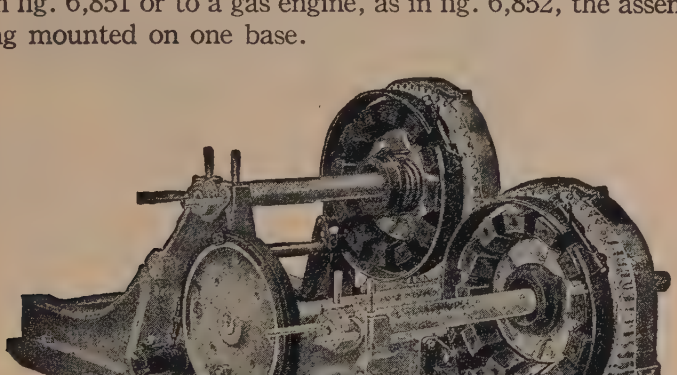


FIG. 6,853.—Mead-Morrison arrangement of frictions and brake for gasoline or electric hoists.

A friction brake is provided so that the drum may be prevented turning when desired. The power of the engine is applied in hoisting by means of a cable, fastened to the drum; the cable is wound upon the drum in hoisting the load, and unwound when it is lowered.

Drums.—Of the many types of drum there are two general classes: the *fixed*, and the *loose* drum. The fixed drum is found on some of the simpler machines designed for that class of work

which requires only the operations of lifting or lowering, or where only single loads have to be handled.

The loose drum is the type mostly used and is so constructed

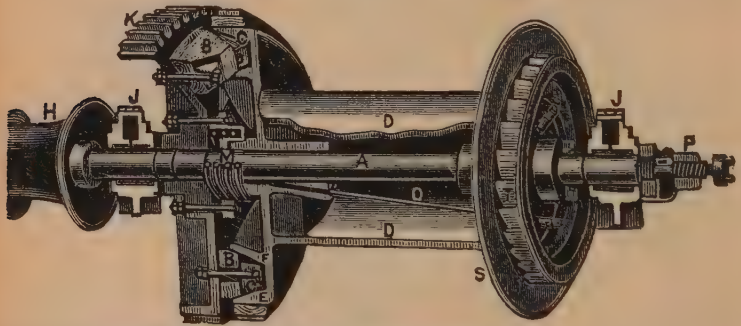


FIG. 6,854.—Sectional view of loose drum. The parts are: A, shaft; B, friction blocks; C, friction flange; D, drum; E and F, friction rings; H, winch head or spool; J, J, bearings; K, gear wheel; P, thrust screw; S, drum flange; T, ratchet teeth.

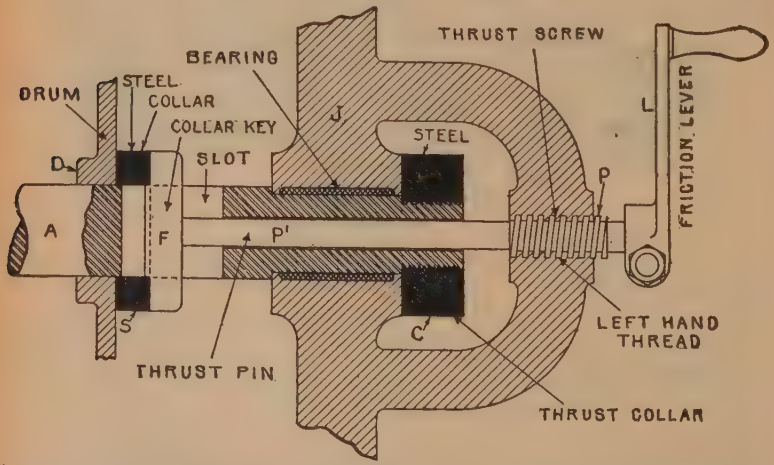
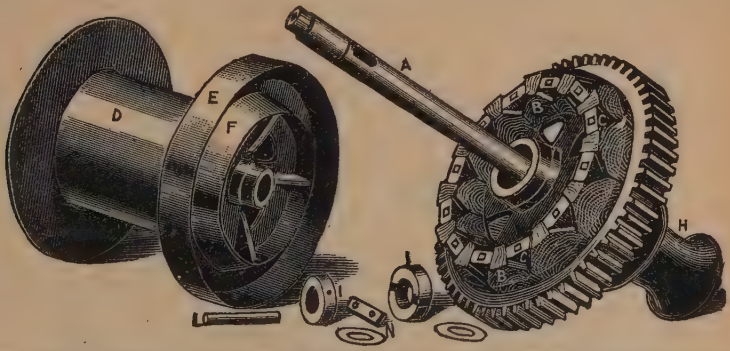


FIG. 6,855.—Sectional view of friction control on loose drum. When the friction lever is turned counter-clockwise, the left hand friction screw pushes the thrust pin to the left. The pin in turn pushes the collar key, collar, and drum in the same direction causing the latter to engage with the friction blocks.

that it may be thrown in, and out of engagement while the engine is in motion, by the action of *friction rings*.

Fig. 6,854 shows the principle of operation.

The drum D, is thrown into gear by a slight endwise movement on its shaft A, produced by turning a lever attached to the screw P, whose end is in contact with a hardened *thrust pin*. The action of this pin is best seen in the sectional view, fig. 6,855. When the engineer turns the friction lever toward him, the thrust screw, which has a left hand thread, pushes the thrust pin against a collar key, which works in a slot cut through the



FIGS. 6,856 to 6,862.—Loose drum and friction control before assembly. The parts are: A, shaft; B, friction blocks; C, block retainers; D, drum; E and F, friction rings forming a V groove on drum flange; H, winch head or spool; I, collar; J, thrust collar; L, thrust pin; N, washers.

shaft. The collar key, together with the collar, is, in turn, pushed against the drum, forcing it into contact with friction blocks to prevent any rotation on the shaft. These blocks consist of sections of hard wood B, bolted to the gear wheel K, which is keyed to the shaft. The adjacent flange on the drum has inclined rings E, F, which register with the bevel on the friction blocks, the endwise movement given the drum by turning the friction lever, bringing the rings into frictional contact with the blocks, thus preventing the drum turning on the shaft since the latter is keyed to the gear wheel K.

When the friction lever is turned clockwise to release the drum, the latter is pushed to the right out of engagement with the friction blocks by the spring M, allowing the drum to revolve freely on the shaft. The loose drum and parts are before being assembled shown in figs. 6,856 to 6,862.

Loose drums are usually fitted with band brakes in order to reduce the wear on the friction blocks. This is especially desirable for long descents, as in tall office building construction, the wear and heat generated being excessive.

Sometimes radial ribs are placed at the friction end of the drum to assist in dissipating the heat, by presenting additional surface for radiation, and inducing air currents.

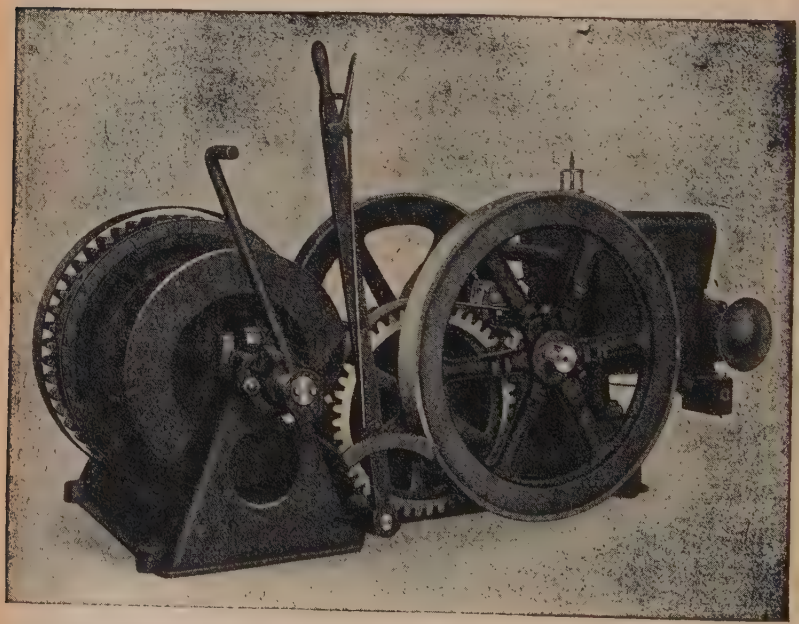


FIG. 6,863.—Fairbanks-Morse hopper cooled gas engine driven hoist. Ignition is by high tension magneto built in as a part of the engine itself and is mounted over the cam gear from which it is operated.

The pile driver illustrates a class of work in which the loose drum is most valuable. Instead of loosening the monkey from the rope and having to re-attach the two before the monkey can be lifted again, the rope remains permanently fastened, and the monkey, in falling, simply unwinds

the rope, the drum revolving on the shaft in a reverse direction, and being again thrown into gear after the blow.

Foot Brakes.—When there is a winch head or spool, as H, fig. 6,854, it is necessary to have a band brake if the spool is to be used at the same time that the load is hanging on the drum. In fig. 6,864 is shown the usual type of brake which consists of a metal band lined with hard-wood segments, and embracing the external circumference of the drum flange.

The brake is operated by the foot, and, as shown, is of the differential type in which both ends of the band are pivoted to the rocker, but at different distances from the center of the brake shaft, so that the strain brought by the load held, tends to turn the rocker in the direction to tighten the brake. By crossing the ends of the band at the rocker, the rotation of the brake shaft is limited, so that the foot lever, when released, cannot be lifted by its counterweight above a fixed and convenient position.

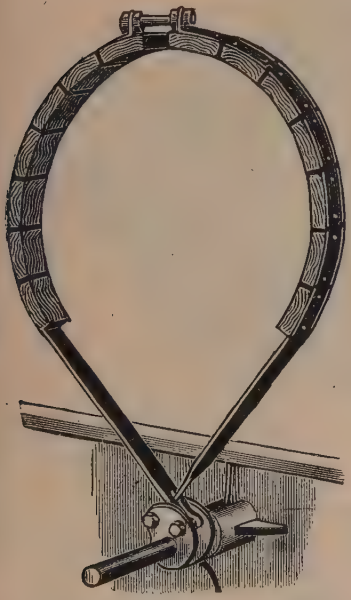


FIG. 6,864.—Band brake for holding the drum with load when disengaged from the friction. The metal band lined with hardwood segments tightly embraces the circumference of the drum when the brake lever is pressed down.

Double Drum Boom Swinging Hoist.—The multiplication of drums is a feature in the development of the hoisting engine, adapting it to service of a universal character, such as the working of a radial derrick where frequently several operations have to be performed at the same time. Fig. 6,865 illustrates a steam hoist adapted to this class of work.

The forward drum is for hoisting the load, and the other for raising the boom. Between the drums and winch heads are two spools for the derrick swinging ropes. With this arrangement, the operations of hoisting the load, raising and swinging the boom can go on simultaneously.

The winch heads are secured to the shaft by a sliding key having a sleeve upon which the swinging spools revolve.

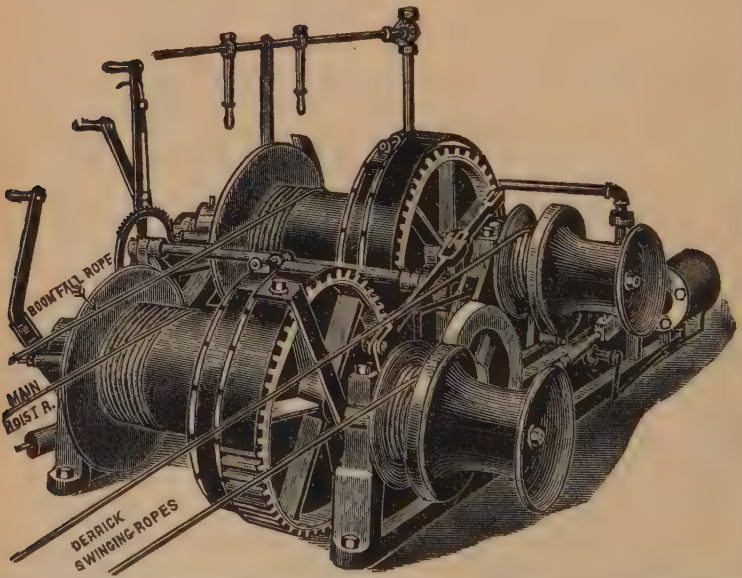


FIG. 6,865.—Double drum steam hoist with boom swinging gear for operating a radial derrick. The machine is so constructed that the operations of hoisting the load, raising and swinging the boom may go on simultaneously.

Friction adequate for the full power of the engine is used between the swinging spools and the winch heads. The frictional contact is produced by cams placed between the swinging drums and the frame of the engine; on the other side are anti-friction collars to take up the thrust.

The operating cams are connected by links to the end of a lever, which is carried on a shaft extending across to the side where the engineer stands, and where the vertical detent lever for operating the swinging device is placed.

In operation, a rope is wound on the bull ring of the derrick and secured to the same in the center, as shown in fig. 6,866. Each of the two ends is fastened to one of the two swinging spools, enough rope being wound on each to give the required amount of motion to the bull wheel. By throwing the lever forward, it engages the friction clutch on that winch, causing it to rotate and wind in the rope, which turns the boom in one direction, the other winch meanwhile paying out the rope.

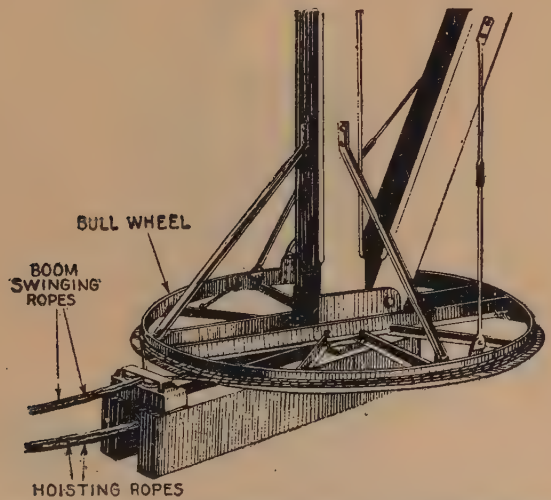


FIG. 6,866.—Base of a radial derrick, showing the bull wheel and boom swinging ropes, also the ropes for hoisting and raising the boom.

The construction of the cams permits this, as the same movement which engages one friction, disengages the other. By throwing the lever backward, the friction of the rear spool is engaged, and the forward spool released. Thus, the boom can be turned in either direction.

The cams operating the frictions are so constructed that when the operating lever is in its central position, there is enough frictional contact in the swinging spools to keep the ropes taut; therefore, when one spool is

winding in the swinging rope, the other has sufficient friction to prevent the rope, which is paying out, overrunning.

The brake and friction levers for the drums are shown in figs. 6,867 and 6,868.

The friction lever of the rear drum, as shown in fig. 6,867, has an extension piece I with a pin, which moves upon the curved surface of an oscillating lever C. The latter has a notch at the lower end, engaging

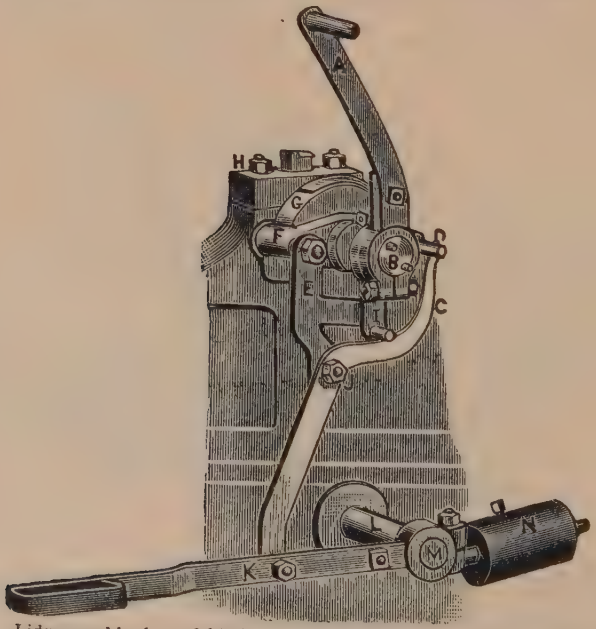


FIG. 6,867.—Lidgerwood brake and friction levers with safety attachment. When the friction lever A, is moved to throw the drum into gear, the pin I, on a projection of the friction lever presses against the curved part of the oscillating lever C, and releases the foot brake.

with a pin extending from the side of the foot brake lever. When the friction lever is moved, for the purpose of throwing the drum into gear, the pin on the end of the friction lever presses against the curved part of the oscillating lever and releases the foot brake.

The friction lever of the front drum, as shown in fig. 6,868, is arranged with a thumb latch and detent engaging with serrated teeth in a quadrant

by which the lever is held in any desired position. The drum is thus securely locked, so that hoisting may go on without any further attention to this lever.

When the lever is moved back, the engineer places his foot on the foot brake lever for a moment and the oscillating lever drops back into its original position, engaging with the pin on the foot brake lever, and thereby locking the brake on the drum. It will be seen that this drum, with the boom hanging from it, is locked fast by the brake, the pawl being usually applied as an additional safeguard.

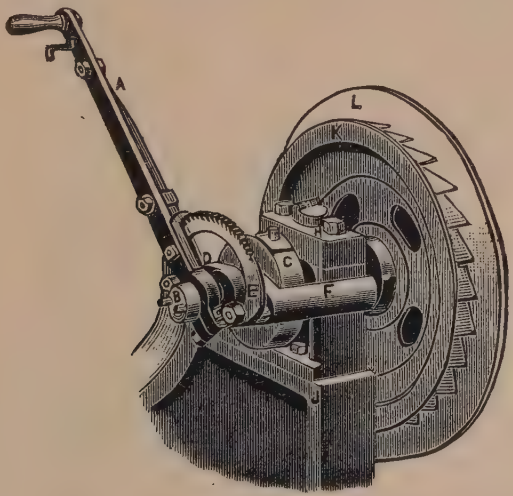


FIG. 6,868.—Lidgerwood friction lever on hoisting drum; a latch and quadrant hold the drum nny position.

Directions for Operating.—The engineer first throws in the front friction drum lever sufficiently to hoist the load. He is then free to handle the boom, either raising or lowering it with the rear drum.

When lowering the boom, he should do it both by the friction lever, and a slight pressure on the foot brake. This prevents the oscillating lever falling into place and locking the brake; it also allows control over the lowering speed of the boom, and as soon as it is lowered far enough,

full pressure is put on the brake lever, and the friction lever thrown out, when the oscillating lever falls into place and locks the brake fast. This use of the two levers in combination for lowering the boom provides against the possibility of the foot slipping off the foot brake.

It is important that the engineer keep the safety lever locked to the foot brake, and also the pawl applied at all times when the boom drum is not in use. The only exception to this rule is when working with a short boom and the time required to throw in the pawl is too valuable to lose. In such cases, the safety lever locked to the foot brake performs all that is required of the pawl and ratchet.

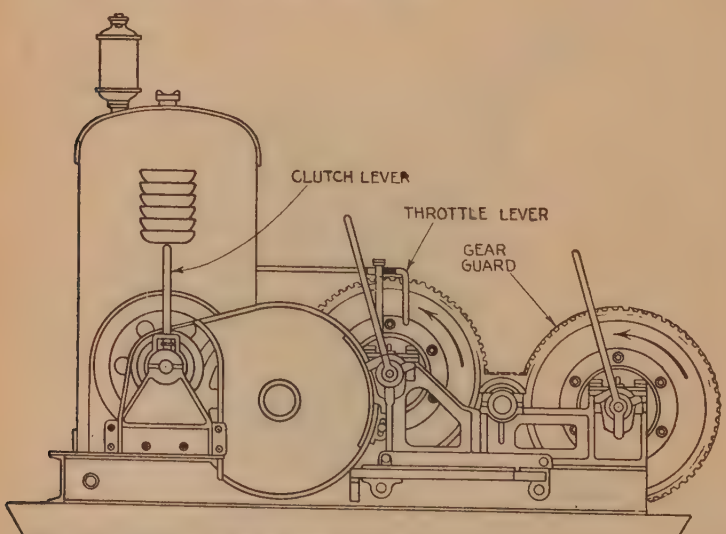


FIG. 6,869.—Novo double drum gas engine hoist powered with four cylinder radiator cooled engine. It will handle two large material elevators. Some contractors have this hoist fitted with an 18 in. or 22 in. diameter drum to handle concrete tower bucket with high speed and a standard drum to handle "Chicago" derrick or miscellaneous steel or platform elevators.

The use of the safety lever locked to the foot brake is desirable with a long springy boom, in chaining or dogging rock after a blast, at which time it may not be known whether the rock, which it is intended to hoist, is free.

The effect of applying the strain for hoisting the rock is to spring the

boom, and if the dogs fly loose, or the chain break, the boom springs back to its normal position, slackening for an instant the boom fall rope, which may throw out the pawl causing the boom to fall.

Hoisting for Deep Mines.—When mining is to be done at great depths, the problem of hoisting the ore becomes more difficult than that met with in ordinary mines. For instance, the variable dead weight of the rope must be taken into account, that is, when the cage is at the bottom, not only is its weight, and that of the one to be hoisted, but also the full weight of the rope, which diminishes as the cage ascends.

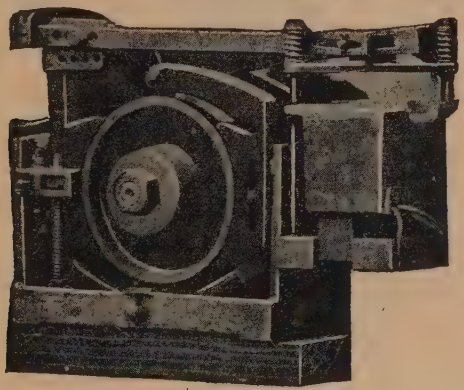


FIG. 6,870.—Novo automatic set solenoid brake.

The rope on the descending side becomes heavier as the cage goes down, with the result that it takes a great effort for the engine to start the cage or skip from the bottom, while as the ascending cage nears the top, the descending cage and rope may even more than balance the total weight of the former, so that the engine has no work to do during that period. This variable load, of course, results in poor economy, and prevents the use of compound engines. The difficulty is overcome by means of a *tail rope* of the same size and weight per foot as the hoisting rope.

The two ends of the tail rope are fastened to the bottoms of the two skips and at the bottom of the shaft the rope passes around a sheave placed in guides, or on a carriage, according to circumstances. This arrangement

balances the hoisting rope, and the load on the engine is, therefore, at all times only the weight of the ore that is being hoisted. This counterbalancing is desirable, aside from the smoothness of operating, because the engine can be better proportioned for the work, resulting in greater economy.

Cone Drum Hoisting Engines.—A development of the single cylindrical drum with two ropes is the double cone drum as shown in fig. 6,871; this is another way of counterbalancing the variable weight of the hoisting rope. The theory of this

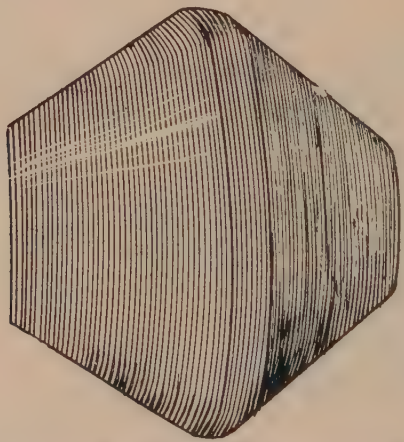


FIG. 6,871.—Allis-Chalmers cone drum. ***A development*** of the single cylindrical drum with two ropes is the double cone drum. This is another way of counter balancing the variable weight of the hoisting rope. The theory of this construction is that as the weight of the rope increases, the radius at which it acts correspondingly decreases, thus equalizing the work of the engine.

construction is that as the weight of the rope increases, the radius at which it acts correspondingly decreases, thus equalizing the work of the engine.

The dimensions of the drum must be proportioned for each particular case, and if used under different circumstances, the drum would fail to fulfill the purpose of its design.

For very deep hoisting in order to balance the great weight of rope, the central portion of the drum would become inconveniently large in diameter, therefore this portion is made cylindrical, and is used by both ropes. This arrangement, while it shortens the drum, makes it impossible to balance the weight of rope.

Reel Hoisting Engines.—The reel hoist is often used where it is not the intention to hoist always in balance, and where no tail rope or compensating device such as a conical drum can be used. The greatest weight to be lifted by any hoist is when the loaded cage is at the bottom of the shaft, consequently all the rope is off the drum or reel. At this point, however, the reel begins to wind on its shortest radius. As the rope winds on the reel, the total load decreases while the leverage of the rope on the reel increases, thus keeping the load on the engine nearly uniform while lifting one cage unbalanced.

Moreover, the rope always leads straight to the head sheave instead of at a considerable angle as occurs when winding on a drum. This makes a compact arrangement which is an advantage in some cases.

Reel hoists are used mostly in the western part of America. As a rule, hoisting is done there from different levels, one car often being hoisted from one level while the car on the other deck may come from another level; under these conditions the hoisting cannot be done in balance.

Capacity of Hoisting Engines.—The horse power required to raise a load at a given speed is equal to

$$\frac{\textit{gross weight in lbs.} \times \textit{speed in feet per minute}}{33{,}000}$$

To this there should be added from 25 to 50 per cent for friction, contingencies, etc. The gross weight includes the weight of the cage, load, and rope. In a shaft with two cages balancing each thus, the net load is taken.

Limit of Depth in Hoisting.—Taking the weight of a hoisting rope, $1\frac{1}{8}$ inches in diameter, at two pounds per foot, and its breaking strength at 84,000 lbs., it should, theoretically,

sustain itself until 42,000 feet long before breaking from its own weight. But taking the usual factor of safety of 7, then the safe working length of such a rope would be only

$$42{,}000 \div 7 = 6{,}000 \text{ feet.}$$

If now a weight of three tons, which is equivalent to that of a cage of moderate capacity with its loaded cars, be hung

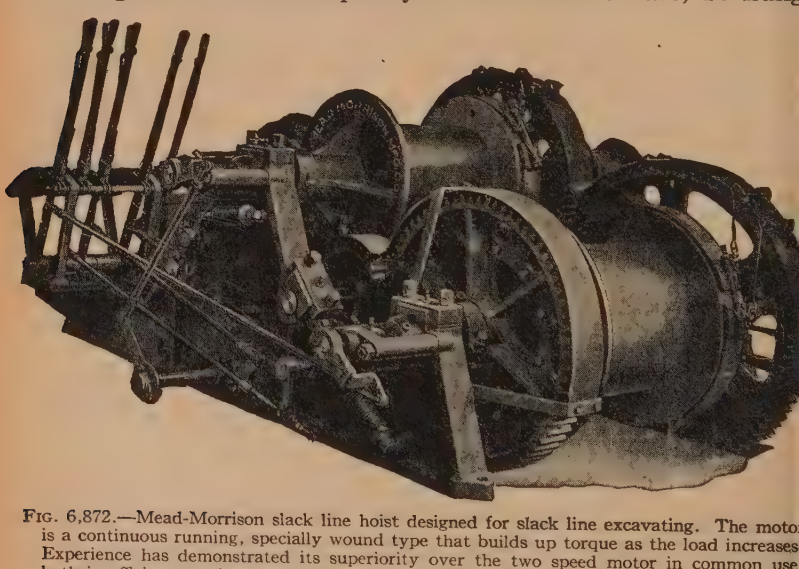


FIG. 6,872.—Mead-Morrison slack line hoist designed for slack line excavating. The motor is a continuous running, specially wound type that builds up torque as the load increases. Experience has demonstrated its superiority over the two speed motor in common use both in efficiency and economy of operation. This hoist has only five levers for complete operation.

to the rope the maximum length at which such a rope could be used with the factor of safety of 7, is

$$6{,}000 - \frac{6{,}000}{2} = 3{,}000 \text{ feet.}$$

The limit may be considerably increased, by using: 1, special steel rope of greater strength; 2, a smaller factor of safety, and 3, taper ropes.

CHAPTER 159A

Strength of Wire Rope

Wire rope in service subjected to several kinds of stresses. The stresses most frequently encountered are direct tension, stress due to acceleration, stress due to sudden or shock loads, stress due to bending, and stress resulting from several forces acting at one time.

Since the strength of a wire rope is determined by its size, grade and construction, these three factors should be considered.

Factors of Safety.—By definition, the factor of safety is: *The ratio of the strength of the rope to the working load.* Thus, a wire rope with a strength of 10,000 pounds and a total working load of 2,000 pounds would be operating with a safety factor of five. Some factors of safety are given in the following table:

MINIMUM SAFETY FACTORS

Type of Service	*Minimum Safety Factor*
Miscellaneous hoisting equipment	5.0
Haulage ropes	6.00
Overhead and gantry cranes	6.00
Jib and Pillar cranes	6.0

MINIMUM SAFETY FACTORS

Table—continued

Derricks	6.0
Small electric and air hoists	7.0
Hot ladle cranes	8.0
Slings	8.0

The table on next page gives the safe loads and weights of wire rope.

Maximum Load on a Wire Rope.—The method of calculation here given is not intended for very close calculations, and should not be used where the rope is subjected to sudden jerks. It will serve as a guide, however, to show whether or not a rope is overloaded. For short periods of time, steam engines and electric motors may be operated with high overloads such as 25% for steam and 50% for electricity. Knowing the horse power of the prime mover provides a basis for this calculation.

When hard pulling is required, the overload values mentioned should be added to the horse power rating.

One horse power is the equivalent of
550 ft. lbs. of work per second;

therefore, the total horse power exerted by a steam engine or electric motor in pulling a rope may be expressed:

$$\text{Horse power} = \frac{\text{feet} \times \text{pounds}}{\text{seconds} \times 550}$$

where feet represents the number of feet of rope wound on the drum in the measured time.

Safe Loads and Weights of Wire Rope*

Dia. in Inches	Approximate Weight Per Foot in Lbs.	Safe Load in Tons of 2000 lbs.		
		Cast Steel	Plow Steel	Improved Plow Steel
	6 x 7 Standing-Rigging Rope			
1/4	.094	.4	.47	
9/32	.12	.504	.59	
5/16	.15	.62	.73	
3/8	.21	.86	1.03	
7/16	.29	1.16	1.39	
1/2	.38	1.5	1.8	
9/16	.48	1.89	2.26	
5/8	.59	2.3	2.76	
3/4	.84	3.3	3.96	
7/8	1.15	4.48	5.36	
1	1.50	5.8	6.96	
1 1/8	1.90	7.28	8.72	
1 1/4	2.34	8.9	10.6	
1 3/8	2.84	10.6	12.5	
1 1/2	3.38	12.5	15.0	
	6 x 19 Hoisting Cable			
1/2	.40	1.5	1.82	2.1
9/16	.51	1.86	2.23	2.62
5/8	.63	2.28	2.8	3.22
3/4	.90	3.26	4.0	4.6
7/8	1.23	4.42	5.44	6.24
1	1.60	5.72	7.8	8.16
1 1/8	2.03	7.2	8.92	10.28
1 1/4	2.50	9.0	10.96	12.6
1 1/2	3.60	12.6	15.6	17.94
1 3/4	4.90	17.0	21.0	24.2
2	6.40	22.2	27.2	33.2
	5 x 19 Marline-Clad			
‡ 3/8x 5/8	.34		1.6	
‡ 3/4x1	.88		4.0	
‡1 x1 1/4	1.36		7.8	
‡1 1/4x1 1/2	1.97		10.96	
	6 x 24 Mooring and Hawser Lines			
3/4	.78	2.72	3.28	
1	1.38	4.74	5.70	
1 1/4	2.16	7.34	8.88	
1 1/2	3.11	10.52	12.72	
1 3/4	4.23	14.24	17.24	
2	5.52	18.40	22.40	

*The sizes and kinds of wire rope listed in this table are those most commonly used in the Sun Shipyard. Safety factor is 5 to 1. These safe loads referred to are for wires when used under ideal conditions.

‡The size referred to here means size before serving, as 3/8" dia., and size after serving, as 5/8", e.g., a wire rope is known as a 3/8" x 5/8" Marline-Clad, some times referred to as Durable Wire Rope.

By rearrangement:

$$\text{Pull on rope in pounds} = \frac{\text{Horse power} \times \text{seconds} \times 550}{\text{feet}}$$

There are now on the right hand side of the equation two unknown factors, time and distance. By placing a marker on the rope or watching the end connection, it is very easy with the aid of a watch and a rule, to determine very closely what these factors actually are.

The time at which these observations are taken should be when the engine or motor is pulling the hardest, as indicated by sound and the slowing down of speed. If the equipment be stalled by excessive loads, these observations should be made just before motion ceases.

Example: A slack line excavator driven by a 25 H.P. electric motor is digging in very hard ground. When the bucket strikes the hard places, it digs 15 feet in 10 seconds. What is the pull on the line?

By using the formula we find:

$$\text{Pull on rope in pounds} = \frac{25 \times 1.5 \times 10 \times 550}{15} = 13{,}750 \text{ lbs.}$$

where the factor 1.5 in the foregoing represents the 50% overload on the motor.

Providing a safety factor of five for the rope on this installation requires a rope with a strength of $5 \times 13{,}750 = 68{,}750$ lbs.

Reserve Strength.—The reserve strength of a wire rope is the strength of the rope exclusive of the outer wires, which are the first to be destroyed by wear and abrasion.

As the number of layers of wires in each strand increases, the reserve strength increases.

Well lubricated ropes have the following approximate reserve strength in terms of total strengths of new ropes.

RESERVE STRENGTHS

Construction	Percentage of Total	
	Outer Wires	Inner Wires (Reserve Strength)
6x7 6x6x7 Tiller Rope	83	17
6x17 Type L *6x25 Type B	73	27
6x19 Seale Patent 8x19 Seale Patent	69	31
6x30 Type G	66	34
6x21 Type M	64	36
6x19 Warrington	59	41
6x19 Type N 8x19	57	43
18x7 Non-Spinning	54	46
6x29 Type P	50	50
6x33 Type R	48	52
6x37 Type S	43	57

*Triangular core wires not included.

How to Find the Pull Required to Lift a Given Weight

When the weight to be lifted and the number of parts at the movable block are known, divide the weight by the number of parts at the movable block to get the mechanical advantage or necessary pull to lift the weight, disregarding any loss by friction. There is always a friction loss around sheaves, and a rule which is safe, but only approximate, is to allow 10% friction loss for each sheave that is 3″ or more in diameter. Add this fractional loss to the load, and proceed as if friction were not present.

Example

How much pull will be required to lift 100 lbs. with 1 single and 1 double block? The tackle consists of sheaves and 3 supporting parts, or has a mechanical advantage of 3. Allow 10% friction loss for each sheave.

Solution:

$3 \times 10\% = 30\%$ = Total amount of friction.

30% of 100 lbs. = 30 lbs.

100 lbs. + 30 lbs. = 130 lbs. = Total amount to be lifted.

$\frac{130 \text{ lbs.}}{3} = 43.3$ lbs. = the pull required to lift 100 lbs.

A more accurate computation is as follows:

$$\frac{100 \text{ lbs.}}{3 \times .90 \times .90 \times .90} = 45.75 \text{ lbs.}$$

The factor .90 represents the 90% efficiency of each sheave and should appear in the denominator of the fraction as many times as there are sheaves in the tackle.

CHAPTER 160

Electric Cranes

Any appliance for lifting and moving loads is far superior to a gang of laborers, especially so in the case of very heavy loads.

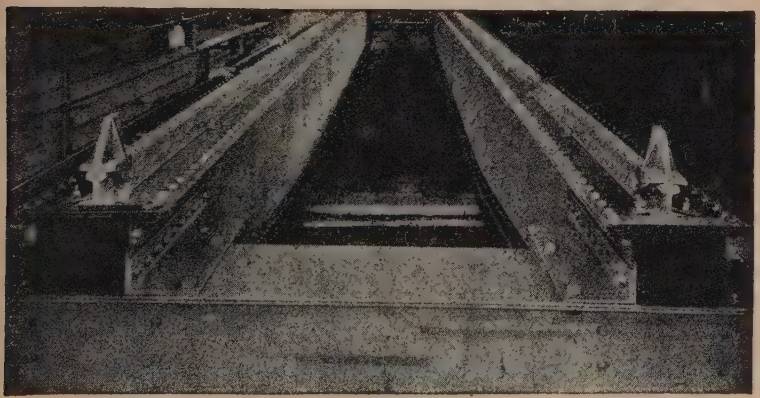


FIG. 6,874.–***Euclid crane construction 1.*** *Double web box girder bridges.* The girders are reinforced by means of channel diaphragms at close intervals. The end trucks are of the box type, made up of heavy channels and plates. The illustration shows the way the girders are notched out and rest upon the top of the end trucks.

By definition, a crane is *a machine for lifting, lowe ing and moving a load in a horizontal direction*, as distinguished from a hoist which simply lifts and lowers a load.

The numerous and diverse conditions of service require a multiplicity of types, and accordingly cranes may be classified:

1. With respect to the character of the horizontal motion, as

a. Rotary
- swinging cranes
- jib cranes
- column cranes
- pillar cranes
- pillar jib cranes
- derrick cranes
- walking cranes
- locomotive cranes

FIG. 6,875.—*Euclid crane construction 2. Gusset plates.* These are used to tie the girders to the end trucks, making it impossible for the crane to weave and get out of square on the runway.

b. Rectilinear
- bridge cranes
- tram cranes
- traveling cran
- gantry cranes

c. Combination rotary and rectilinear.

In addition to these, there are some miscellaneous types known as

1. Sheer legs;
2. Transporters;
3. Telphers
   - cableways
   - mono-rail systems

The following definitions of the various types show the inherent features of each:

Bridge cranes.—Having a fixed bridge spanning an opening and a trolley moving across the bridge.

Column cranes.—Identical with the jib cranes, but rotating around a fixed column (which usually supports a floor above).

FIG. 6,876.—***Euclid crane construction 3. Heavy duty mill type trolley.*** The two side housings are iron castings. The separator girt is made up of structural steel and steel castings.

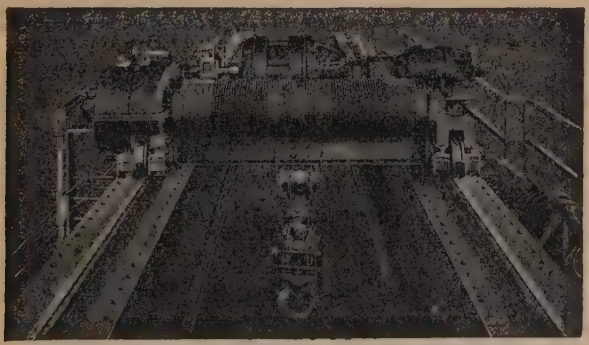


FIG. 6,877.—***Euclid crane construction 4. Another view of mill type trolley showing track wheel bearings.*** The drum is scored right and left hand, so that the load is always equally distributed on both girders. This cut also shows the separator girt connecting the two side frames.

FIG. 6,878.—***Euclid crane construction 5.*** *Hoisting gear train.* Wide face coarse pitch gears are used. The illustration also shows the shoe type electric brake mounted on the motor shaft and the Weston type mechanical load brake on the intermediate shaft.

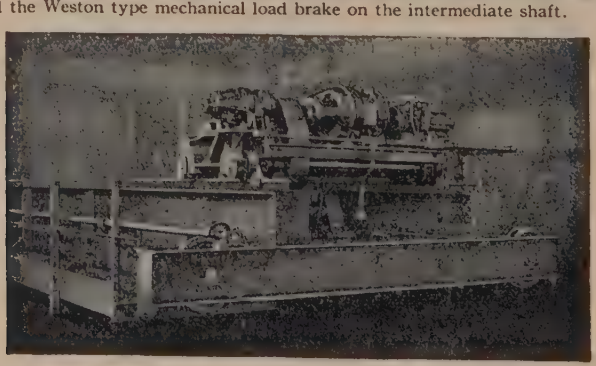
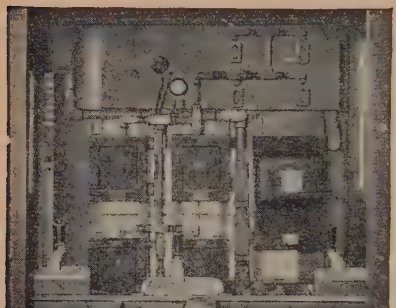


FIG. 6,879.—***Euclid crane construction 6.*** ***End truck construction and driving side of the crane trolley.*** In design the line shaft bearings are closely spaced.

Derrick cranes.—Identical with jib cranes, except that the head of the mast is held in position by guy rods or stiff legs, instead of by attachment to a roof or ceiling.

FIG. 6,880.—***Euclid crane construction 7.*** *Bridge drive mechanism.* The illustration also shows the motor mounting between the bridge motor and the gear housing.

FIG. 6,881.—***Euclid crane construction 8.*** *Side view of trolley, showing type of bridge drive gear case sometimes used.* The drive is oil tight. The shoe type bridge brake is operated by means of a foot pedal in the operator's cab. This brake is mounted on an extension of the motor shaft.



Gantry cranes.—The same as a traveling crane except that the bridge member is supported on structural legs of suitable height which are provided with wheels and suitable gearing, so that the crane may be propelled bodily along the tracks which are on the ground.

Jib cranes.—Having rotation and a trolley traveling on the jib.

Locomotive cranes.—Consisting of a pillar crane mounted on a truck, and provided with power capable of propelling and rotating the crane, and of hoisting and lowering the load.

FIG. 6,882.—***Euclid crane construction 9.*** *Interior view of crane cab.* All instruments are enclosed in metal cabinets and all the wiring in metal conduit with porcelain outlets. A fully enclosed safety type main line switch is provided, arranged so it can be padlocked in open position to insure safety of men working on crane.

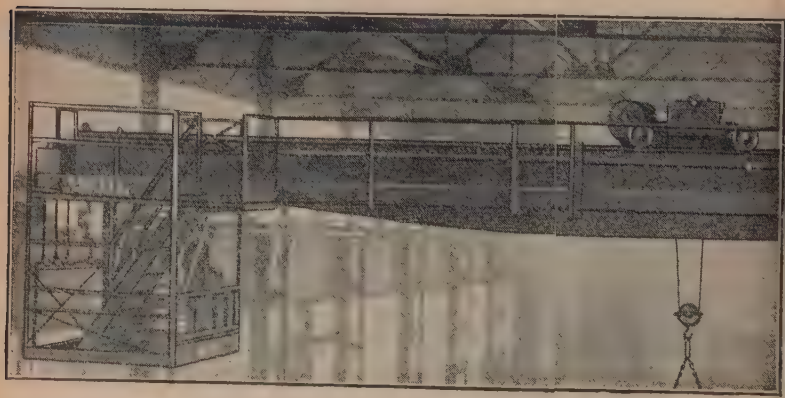


FIG. 6,883.—***Euclid crane construction 10.*** *Box girder type crane* having moderate duty trolleys in place of the mill type trolley. The trolley is shown in detail in figs. 6,884 and 6,885.

Pillar cranes.—Having rotation only, the pillar or column being supported entirely from the foundation.

Pillar jib cranes.—Identical with the last, except in having a jib and trolley motion.

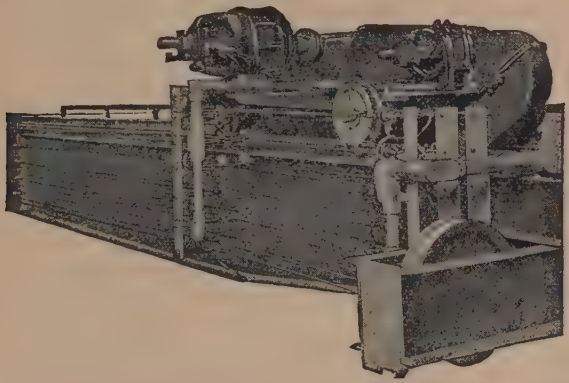


FIG. 6,884.—***Euclid crane construction 11.*** *Moderate duty trolley.* All the hoist mechanism is located in a one piece housing. This housing rests upon two heavy saddle type steel castings. This entire trolley is machined to jigs and all parts are interchangeable. It is used regularly up to 5 tons capacity and intermittently up to 15 tons.

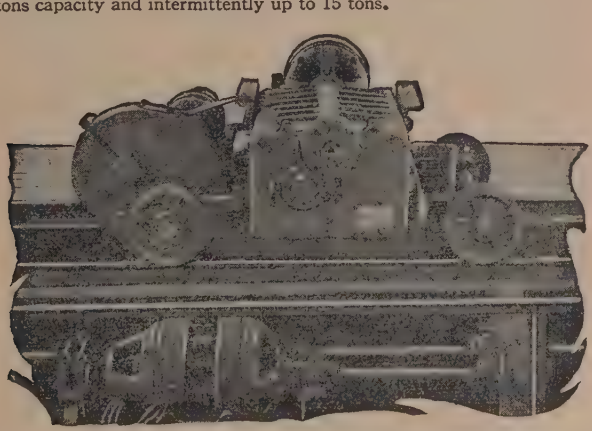


FIG. 6,885.—***Euclid crane construction 12.*** *Another view of moderate duty trolley.* The illustration also shows the disc type electric brake that is located on the end of the motor shaft.

FIG. 6,886.—***Euclid crane construction 13.*** *Multiple disc automatic load brake.* The center plate is stationary. The brake is fully released during the hoisting movement and automatically sets when the hoist motor comes to a stop. The load can be lowered only by reversing the motor.

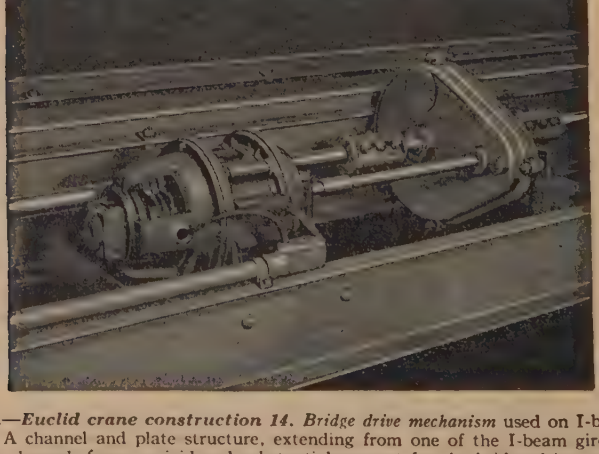


FIG. 6,887.—***Euclid crane construction 14. Bridge drive mechanism*** used on I-beam girder cranes. A channel and plate structure, extending from one of the I-beam girders to the outrigger channel, forms a rigid and substantial support for the bridge drive motor. The driving pinion and gear are enclosed in oil tight housing, shown revolving in an oil bath.

Rotary bridge cranes.—Combining rotary and rectilinear movements and consisting of a bridge pivoted at one end to a central pier or post, and supported at the other end on a circular track, provided with a trolley moving transversely on the bridge.

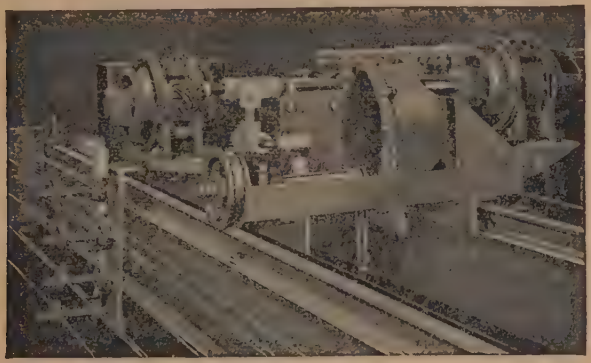


FIG. 6,888.—***Euclid crane construction 15.*** *Trolley drive mechanism* used on small capacity cranes. The gear train for the trolley drive is housed in one oil tight compartment, revolving in an oil bath. The illustration also shows the method of mounting the controllers and rheostats on the trolley when the service conditions make such an arrangement desirable.

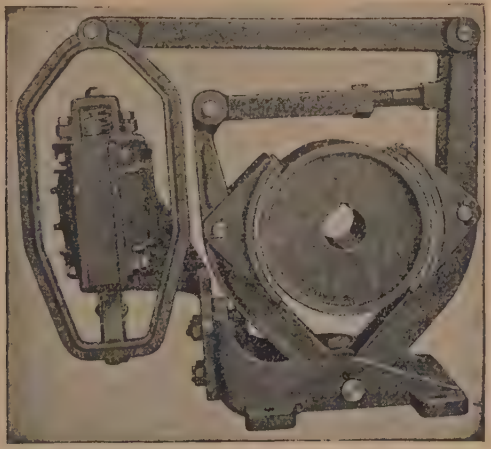
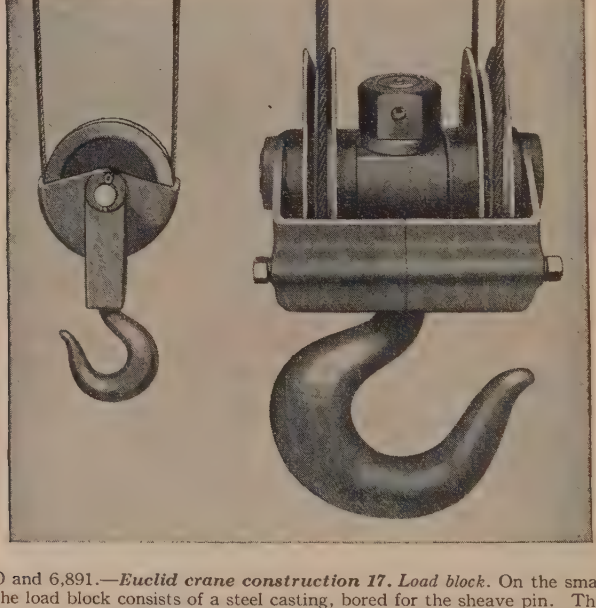


FIG. 6,889.—***Euclid crane construction 16.*** *Electric brake.*

Swinging cranes.—Having rotation, but no trolley motion.

Tram cranes.—Consisting of a truck, or short bridge traveling longitudinally on overhead rails, and without trolley motion.

Traveling cranes.—Consisting of a bridge moving longitudinally on overhead tracks, and a trolley moving transversely on the bridge.



FIGS. 6,890 and 6,891.—***Euclid crane construction 17.*** *Load block.* On the smaller sizes of cranes, the load block consists of a steel casting, bored for the sheave pin. The load hook is carried on a heavy lug formed in the base of the steel housing, In the larger sizes the sheaves are mounted on a steel trunnion, which is bored at the center for the shank of the hook. The entire load is thus carried on the trunnion, the hook block casing serving only as a housing for the sheaves. All lifting hooks are steel forgings.

Walking cranes.—Consisting of a pillar or jib crane mounted on wheels and arranged to travel longitudinally upon one or more rails.

Essentials of Rotary Cranes.—In this type of crane, the construction is such as will permit the load to be lifted, lowered and moved radially. An example of rotary crane is shown in

fig. 6,892, which illustrates the essential features of a locomotive jib crane.

The area served by a locomotive jib crane is equal to *twice the maximum radius of the jib*, and a length depending on the length of track laid.

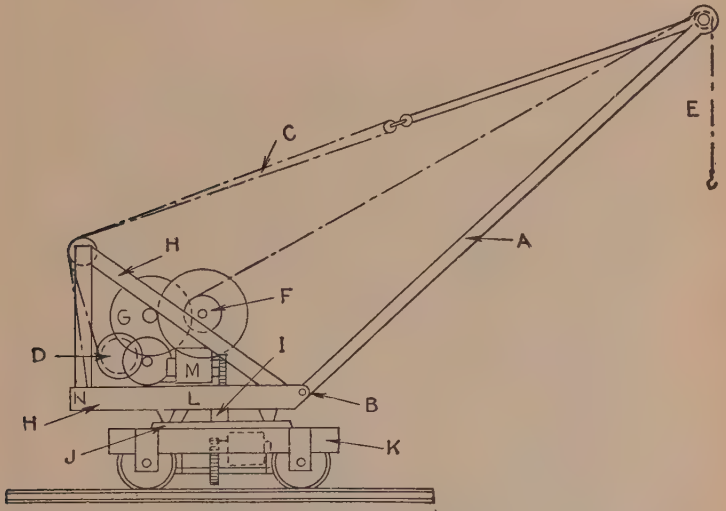


FIG. 6,892.—Electric locomotive jib crane. ***The essential parts are:*** A, jib; B, jib pivot; C, rope gear serving as a brace for jib, and which controls the radial position of jib D, jib shifting drum; E, hoisting rope leading from hook; F, hoisting drum; G, hoisting motor; H, framing; I, pin; J, turning or slewing wheel; K, truck; L, pinion; M, turning and propelling motor. As shown in the figure, the hook, which engages the load, hangs from the end of the jib A, which is supported by the piece B, and rope C, which leads to the drum D. By winding in or paying out the rope C, the radius of the jib in the horizontal plane can be increased or diminished. The rope for hoisting the load is brought over a pulley at the head of the jib and led to the drum F. Drums D, and F, are usually arranged to be driven from one motor G, clutches being so arranged that when the motor is in gear with the one drum, it is out of gear with the other. The jib and hoisting gear are carried by the framing H, which turns upon the pin I, the turning or slewing being accomplished by means of the wheel J, which is secured to the platform of the truck K, and pinion L, (carried by bearings in the framing H), which is driven by the motor M. It is usual for the framing to be capable of making a complete circle. The motor M, is also used to drive the truck along the rails. A vertical shaft driven from this motor passes through the pin I, and drives one or both of the axles by means of bevel gear. Clutches are provided so that the motor M, may be used for slewing or traveling. The load is balanced by the weight N. A foot plate for the operator is provided on the framing just in front of the balance weight, and the controllers and clutch levers are within easy reach.

The effective radius of the jib is equal to its projection on the horizontal plane passing through the pivot on the lower end of the jib.

The most economical position of the inclined brace in a jib crane is *that position in which the inclined brace intersects the jib at a distance from the mast equal to* $^4/_5$ *of the effective radius of the jib.*

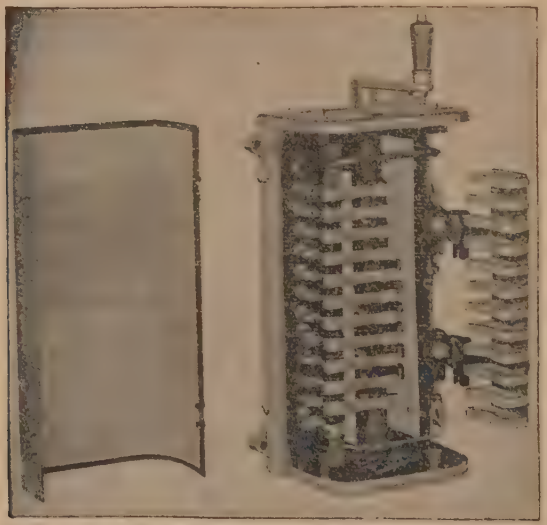


FIG. 6,893 and 6,894.—***Euclid crane construction 18. Controller.*** It is of the drum type with fingers of the non-stubbing type. Both finger tips and contact segments are reversible. *D.c.* controllers are provided with powerful blow out coils to prevent injurious arcing.

Essentials of Rectilinear Cranes.—This form of crane differs from the preceding type in that the load is moved linearly instead of radially. The essential features of rectilinear cranes are shown in fig. 6,895, which illustrates a rectilinear crane of the traveling type.

In construction, a pair of cross girders AA, known as the bridge, are

supported on the end carriages BB. The wheels of the end carriages run on rails mounted on elevated structures or *gantries* CC. The purpose of the crane is to lift, transport, and deposit loads anywhere within an area a little less than the width between the gantries and of a length depending on the length of the gantries. Rails are laid on the cross girders AA, and a crab or trolley runs on these rails.

The trolley has two motions, each driven by its own motor.

The hoisting motion, for lifting and lowering the load, consists of the drum D, driven through suitable gearing by the motor E. To traverse the crab along the cross girders, the motor F, drives one pair of wheels through

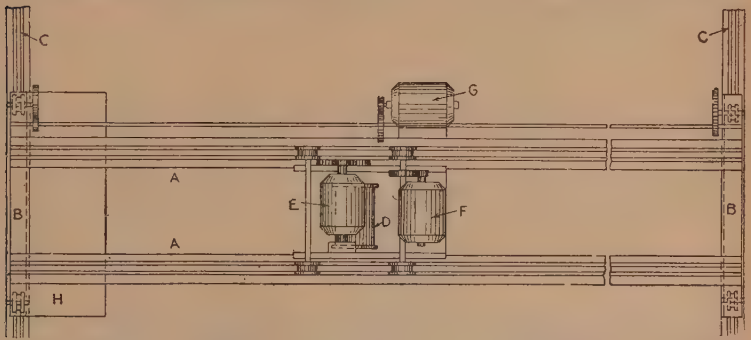


FIG. 6,895.—Electric traveling crane. ***The parts are:*** AA, cross girders known as the *bridge*; BB, end carriages; CC, elevated track structure or *gantries*; D, hoisting drum; E, hoisting motor: F, transverse propelling motor; G, longitudinal propelling motor; H, cage or operator's platform.

gearing. For the purpose of traveling the crane along the gantry, the motor G, is mounted at the center of one of the cross girders, and from each end of the motor, a shaft is led to drive one wheel in each of the end carriages. The traveling motor is mounted at the center of the cross girder to obtain an equal amount of twist in both parts of the shafting so as to avoid cross wind.

Essentials of Combined Rotary and Rectilinear Cranes.—A modification of the traveling crane, which combines the functions of the two classes, rotary and rectilinear, consists in pivoting one end of the bridge of a traveling crane and supporting the other end on a circular gantry as shown in fig. 6,896.

The illustration shows that most of the mechanism is identical with that of the traveling crane.

Essentials of Transporters.—By definition a transporter is *a lifting and transporting machine designed to carry loads between two fixed points*. It is used chiefly for handling comparatively light loads at quick speeds and employed largely for the conveyance of materials such as coal in bulk. For the latter service it is provided with an automatic grab instead of a hook. Fig. 6,897 shows the essential features.

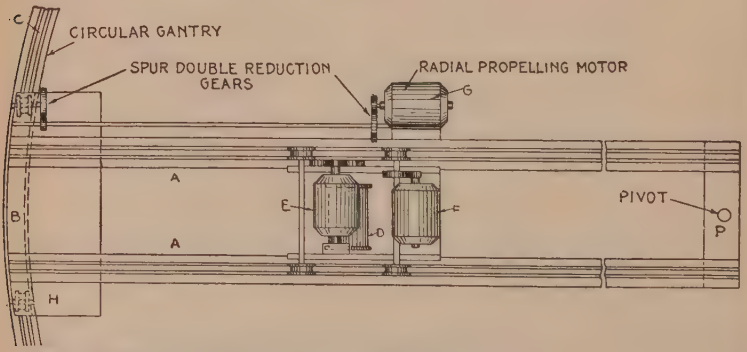


FIG. 6,896.—Electric combined rotary and rectilinear crane. ***In construction*** most of the parts are identical with those of fig. 6,895, and the letters on these parts are the same for each figure. This type differs from fig. 6,895, in the replacement of one gantry by a pivot P, and the other straight gantry by a circular gantry which may be either an arc or a complete circle as desired. One end of the bridge is pivoted at P, and at the other end, a section of the circular gantry is shown. The circular gantry may continue all the way around or only for a short arc, as may be desired. The figure clearly shows that the rotary motion is obtained by operating motor G, and the rectilinear motion, by motor F, while hoisting and lowering is effected by motor E.

A transporter requires from ½ to 1 minute to perform a complete cycle The weight of a grab load is from 1 to 1½ tons.

Crane Motors.—These are designed *for severe intermittent varying speed service.*

Such conditions of operation require very rugged construction in order to

insure maximum reliability and minimum operating expense. The design should be such that all parts are readily accessible to permit the substitution of spare parts, with very little delay, in case of accident. The multiplicity of accompanying cuts illustrate very fully the characteristic features of crane motors.

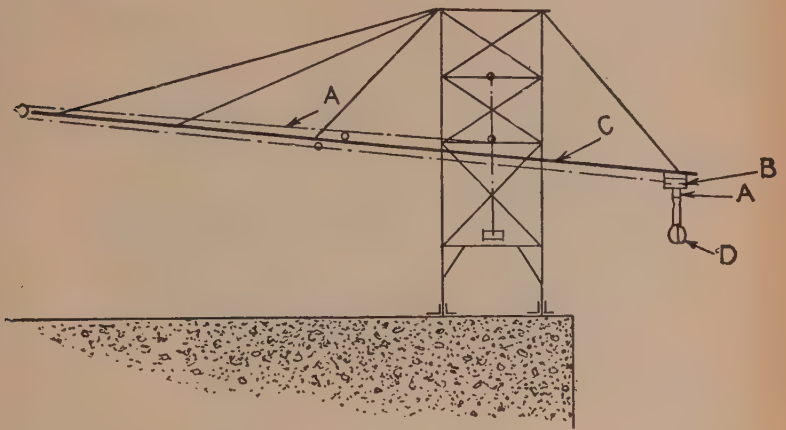


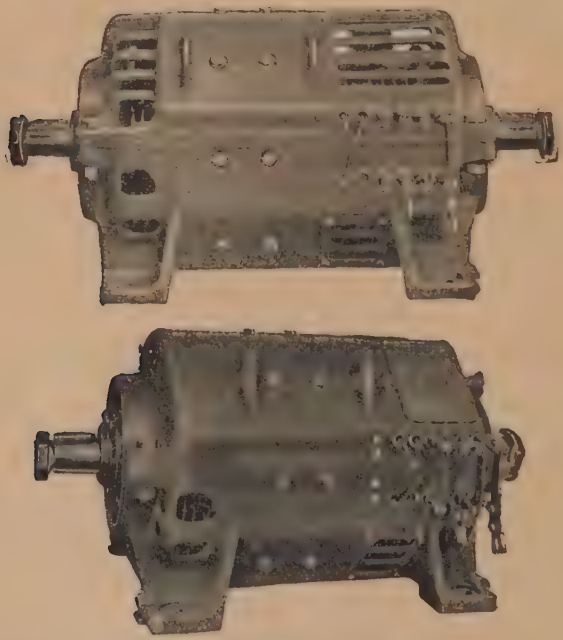
FIG. 6,897.—Electric transporter. ***The parts are:*** A, load rope; B, carriage; **C,** beam; D, grab. ***In operation,*** the grab being full, the electrically driven drum winds in the load rope A. The carriage B, being held by a trigger at the bottom end of the beam C, the winding in of the rope lifts the grab. When it is heaved right up to the carriage, it locks itself to it, and at the same time lets go the trigger. The carriage is pulled along the beam, but as the rope is now single purchase, the carriage is pulled along at double the speed at which the load was hoisted. On arriving at the top end, the carriage is held by a trigge and the grab is freed from the carriage. The motor is now reversed, and the grab, after being lowered a given distance, discharges its contents. The motor is again reversed, thus hoisting the grab up to the carriage, to which it locks itself and frees the trigger. On reversing the motor, the carriage runs down the beam, and at the botton end is caught by the trigger, while the grab is released and continues to run down till it plunges into the material, thus completing the cycle.

Power Required to Drive Cranes.—The power required to drive the different parts of cranes is determined *by allowing a certain friction percentage over the power required to move the dead load.*

On hoist motions 33⅓% is allowed for friction of the moving parts, thus giving a motor of ⅓ greater capacity than if friction were neglected.

For bridge and trolley motions, a journal friction of the track wheel axles of 10% of the total weight of the crane and load is allowed. There is then added an allowance of 33⅓% of the horse power required to drive the crane and load plus the track wheel axle friction, to cover friction of the gearing.

In selecting motors, the most important consideration *is the maximum starting torque which the motor can exert.*



FIGS. 6,898 and 6,899.—***General Electric crane d.c. motors 1. For main hoist.*** Series wound, ventilated (fig. 6,898) or protected type (fig. 6,899) mill motors are used, having shunt wound spring set, shoe type, solenoid brakes, if solenoid brakes be needed. These types of motors are necessary on account of their ability to dissipate heat, but the motor should be protected from weather by a simple, sheet iron house, which provides for ventilation. ***Rack motion:*** Series wound, ventilated or protected type mill motors are used. They should be protected from weather in the same manner as hoist motors. Shunt wound, shoe type, spring set brakes for motor mounting are used in most cases. Automatic magnetic control, arranged either for plugging or dynamic braking for retarding the trolley, is used.

With alternating current motors, this is less than with direct current motors, requiring a larger motor, particularly on the bridge and trolley motions which require the greatest starting torque.

Automatic Electro-magnetic Brakes.—It is customary to fit the hoisting motion with an electro-magnetic brake. This may

FIG. 6,900.—***General Electric crane d.c. motors 2. For boom hoist.*** Series wound, totally enclosed, crane type motors with shoe type, series wound, spring set solenoid brakes and dynamic braking drum controller with low speed, heavy duty resistors are used.

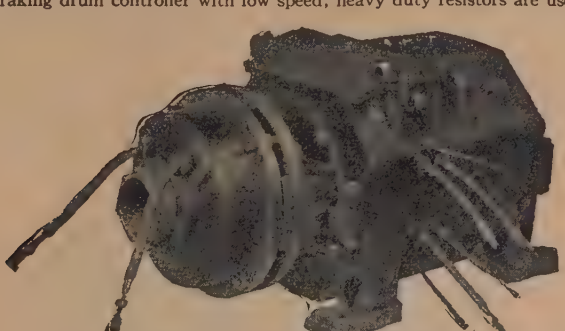


FIG. 6,901.—***General Electric crane d.c. motors 3. For bridge propelling.*** Series wound, totally enclosed, weatherproof, crane type motors are used, equipped with shunt wound, weatherproof solenoid brakes of either the disc type or shoe type. The brakes are oversize in order to provide high torque for holding in a wind storm. Drum type controllers, suitable for either one or two motors, are used. These controllers have dynamic braking, slow down and creeping speed points to provide the maximum safety when propelling in a wind storm, and the ability to stop smoothly. This motor has the disc type brake.

consist of a band brake which is normally kept on by a spring or weight and released by an ironclad solenoid, or it may be a disc brake in which the discs are normally pressed together by a spring, an electro-magnet being provided to pull back the pressure plate and release the discs.

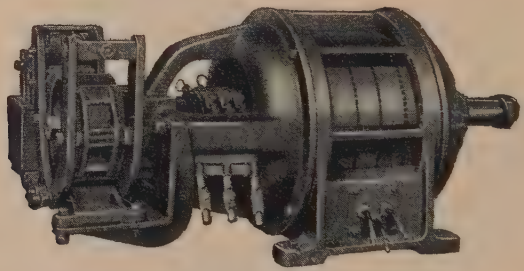


FIG. 6,902.—***General Electric a.c. crane motors 1.*** *For main hoist.* Open motors are used for all except the most severe rapid service. For the latter service, mill type motors or large motors of mill type construction with outboard bearings are used. For very high speed hoists, running at 1000 ft. per min. and above, specially designed, low speed, high torque, low fly wheel effect motors, direct coupled to the hoist drum, are used. This construction eliminates gear losses, prevents wear and noise, and provides for the quick start which is consistent with the high rope speeds. For controlling small hoists running at approximately 100 ft. per min. drum type controllers and shoe type solenoid brakes are employed. Magnetic plugging controllers are employed on medium and high speed hoists. For some large high speed hoists, automatic magnetic controllers with dynamic braking are used, requiring either a separate motor generator set or preferably, where space permits, a direct coupled, direct current motor for separate excitation. For all sizes of hoists, where the bridge builder takes care of the necessary braking, plain reversible or non-reversible automatic magnetic control is used.

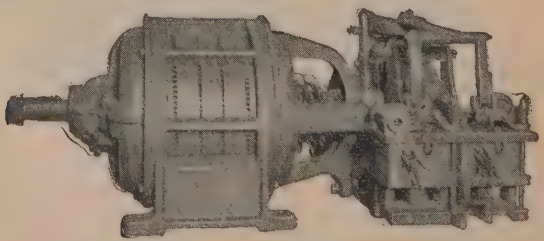


FIG. 6,903.—***General Electric a.c. crane motors 2.*** *For boom hoist.* Open, crane type motors with solenoid load brakes and special rheostatic control are required. This permits the boom to be lowered by regenerative braking and stopped smoothly by the solenoid load brakes.

The coil of the solenoid or electro-magnet is in circuit with the hoisting motor, so that when current is switched on to the motor, the brake is released, and when it is switched off, the brake is applied. This makes an excellent safety device but as it can only be off or full on, it cannot be used to regulate the descent of the load when lowering.

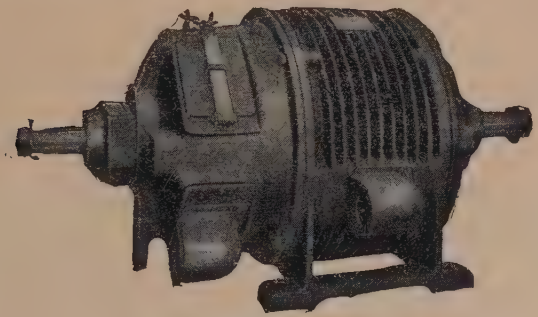


FIG. 6,904.—***General Electric a.c. crane motors 3.*** *For bridge motion.* This requires open crane type motors with shoe type solenoid brakes in a sheet metal house for protection against weather or totally enclosed crane motors, with shoe type brake using a sheet metal housing for the brake. Totally enclosed, mill type motors with shoe type solenoid brakes, having a sheet metal housing for the solenoid brakes, are used in some cases, especially where duplicates of other equipment in a mill are desired. If one motor alone be used for propelling the bridge, it is advantageous to equip it with a multiple magnet solenoid brake so that one magnet can be used for giving a smooth stop and the other magnet for giving an extra high torque for holding in a wind storm. Where two or four motors are used for propelling the bridge, it is advantageous to equip the motors with solenoid brakes and, in stopping to set one-half of the solenoid brakes first to provide for a smooth stop and then to set the remainder of the solenoid brakes for holding against wind. Manual controllers, for either one or two motors, and equipped with necessary drift points for handling solenoid brakes as outlined above, are provided.

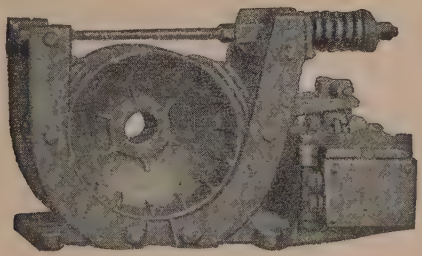


FIG. 6,905.—***General Electric shoe type spring set brake*** for motor mounting

In cases where the driver has access to the gear, as in locomotive jib cranes and derricks, an addition may be made to the electro-magnetic brake in the form of a hand or foot release lever, by which the brake can be released or its pressure regulated. Loads are then hoisted by the motor, and are allowed to run down by their own weight, the speed of descent being regulated by the brake.

Where the driver operates the gear from a distance, the arrangement just described is not practicable, and some automatic or electrically controlled arrangement must be used to check the speed of descent of the load.

Automatic Mechanical Brake.—A common arrangement is the automatic mechanical brake. The brake is usually of the

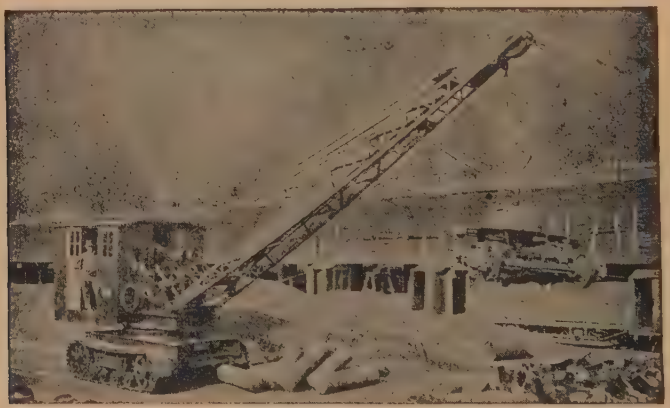


FIG. 6,906.— Brownhoist electrically operated crawler crane equipped with *lifting magnet.*

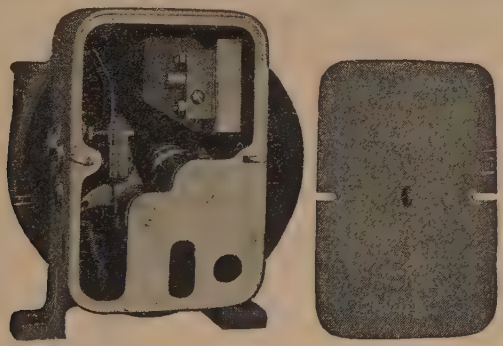
disc type, and is arranged to allow the gear to run freely in the direction of hoisting, but holds it from running in the opposite direction, being applied by a screw, or it can be arranged to be operated automatically by the load.

The brake is released by running the motor in the direction for lowering. As the motor releases the brake, the load tends to put it on again; consequently the speed of descent depends upon the speed of the motor, and this can, of course, be regulated by the driver by means of the controller.

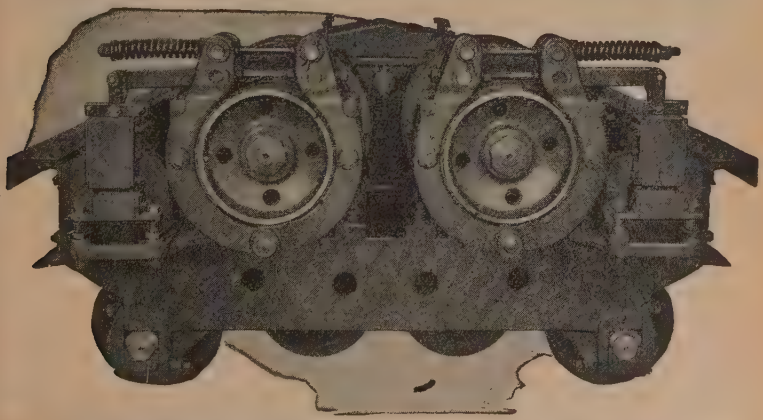
Eddy Current Brake.—This type of brake is only used to a limited extent.

It consists of a wheel, generally of copper or other metal of low electrical resistance, which is arranged to rotate between the poles of an electro-magnet. The wheel is driven by the descending load, and eddy currents are generated in it, which give rise to a retarding torque.

The eddy currents and the consequent torque are regulated by varying the strength of the magnet by means of a regulating switch and resistance.



FIGS. 6,907 and 6,908.—Milwaukee limit switch with cover removed showing internal mechanism.



FIGS. 6,909.—Milwaukee shoe type solenoid motor brake. The shoes are lined with asbestos.

Rheostatic Brake.—For this form of braking, the controller is provided with several positions on the lowering side, called *brake points*.

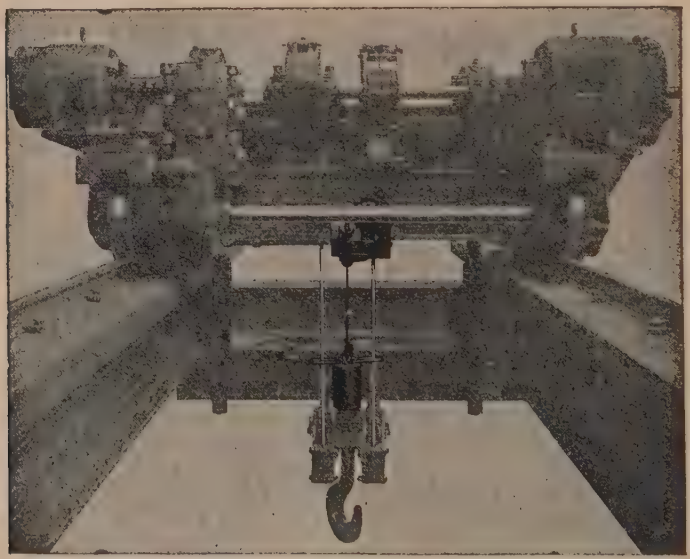
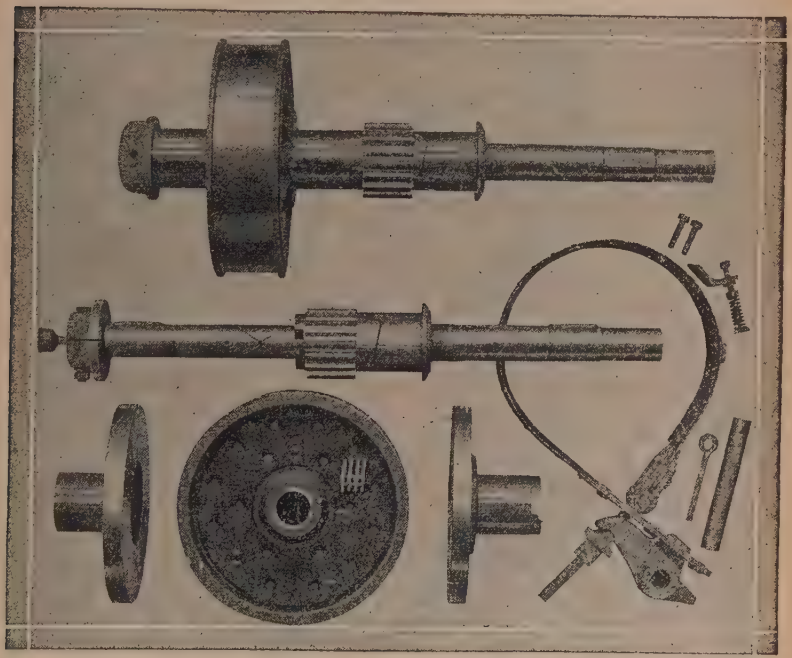


FIG. 6,910.—Milwaukee limit switch applied to two motor trolley. ***To prevent overhoisting*** and breaking of sheaves or other parts of the hoisting mechanism the hoist motor line is opened automatically by the limit switch when the hook reaches its highest safe position. The switch is arranged with a quick break mechanism which prevents it slowly or partly opening at the contacts. It is connected in series with the operating coil of a contactor mounted on the switchboard. This contactor opens the hoist motor circuit in the hoisting direction. When the limit switch has been tripped the operator can immediately lower his hook by simply reversing his controller. When the hook has been lowered below the tripping point the switch automatically resets.

In these positions the controller alters the connections of the motor to those of a series dynamo, so that it generates current when driven by the descending load, the energy being absorbed by the controller resistance. The speed of lowering is regulated by varying the resistance.

Regenerative Control.—Instead of a series motor, a shunt wound motor may be used to drive the hoisting motion.

A shunt motor has the advantage that its speed can be efficiently regulated over a fairly wide range by inserting resistance in its field circuit. By this means considerable variation of speed in lifting and lowering may be obtained without the necessity of having variable speed gear in the hoisting train, and when lowering, the shunt motor, if overhauled by a load, becomes a dynamo and feeds current back to the circuit, thus automatically controlling the speed of lowering. This system has been in use to a limited extent for some years.



FIGS. 6,911 to 6,921.—Milwaukee mechanical load brake disassembled. Trolleys operating on alternating current are equipped with a mechanical load brake. This brake serves a double purpose with the aid of the motor brake. It sustains the loads after being hoisted and also controls the speed in the lowering direction. The load is, at all times, under complete control of the crane operator and cannot be lowered faster than the speed of the motor permits since the mechanical brake will automatically retard the speed of the load in lowering should it become excessive. It is automatic in action and is operated by running the hoist motor in the lowering direction. The brake is of the Weston disc type equipped with a differential retaining band and discs fitted with asbestos friction linings.

Collector Gear.—To convey current from the mains to the moving crane a collector gear, generally similar to that used for electric tramway work, is employed. For overhead cranes copper

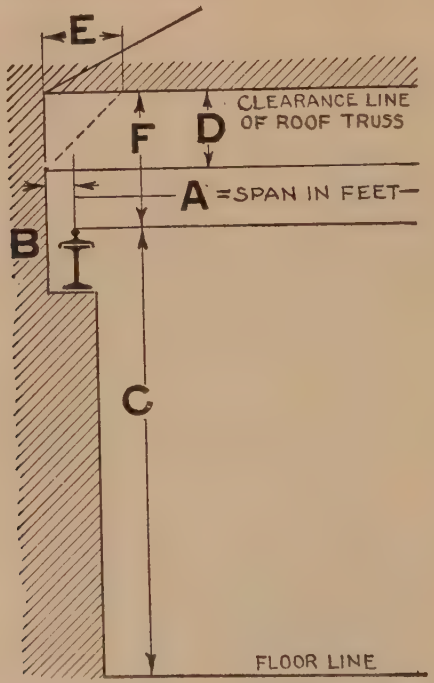
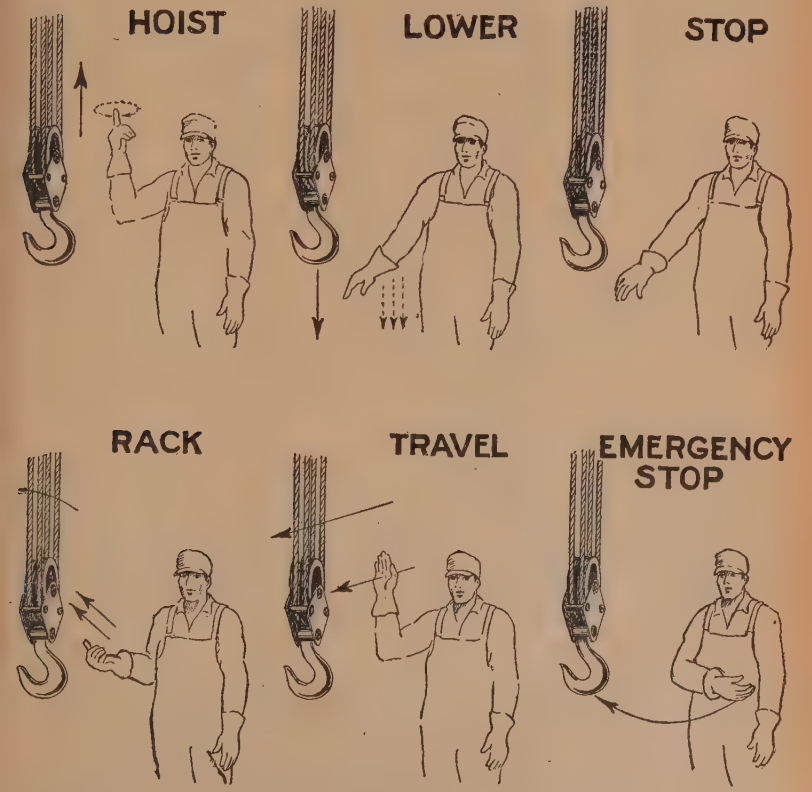


FIG. 6,922.—Section of shop showing information required in selecting a crane. ***Load,*** maximum in net tons; ***speed,*** if special for any function be preferred; ***style,*** outside or inside service; ***current data,*** whether *d.c.* or *a.c.*, giving voltage cycle and phase; ***clearance dimensions,*** A, span; B, end clearance; C, distance from top of runway rail to floor; F, overhead clearance.

wires about one-quarter to three-eighths inches in diameter are stretched along the gantry, being supported at the ends by globe strain insulators. Trolley wheels or slides, mounted on the end carriage, make contact with these wires.

From the trolley wheels or slides, insulated cables are led to the switches and controllers, and to another set of trolley wires on the cross girders. Contact with these wires is made by sliders or trolley wheels on the crab, from which cables are led to the motors.

For locomotive jib cranes overhead or underground collector gear is used similar to that used for tramway cars. As derrick cranes only swing backward and forward through a portion of a circle, collector gear is not



Figs. 6,923 to 6,928.—Crane signals for operator's hoisting movements.

necessary. Connection from the supply mains to the moving part of the crane can be satisfactorily made by means of flexible armoured cable.

Controllers.—The class of controller most commonly used for crane work is that known as the drum, or tramway type.

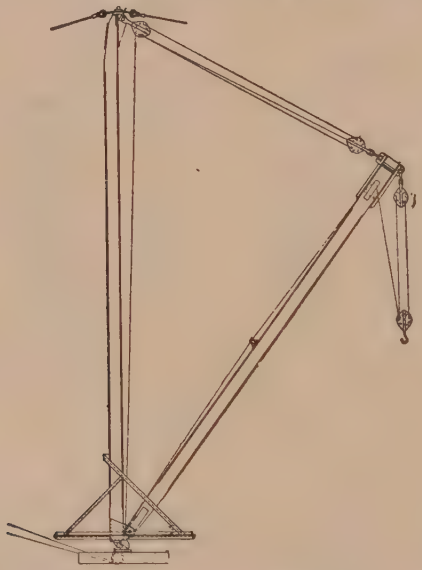


Fig. 6,929.—Guy derrick with bull wheel and swinging gear. ***In construction,*** all the fittings except the foot irons and sheaves are made of forgings or structural shapes. The foot block and mast step are made with a ball and socket universal joint. Uneven setting or a settling of the derrick supports cannot make this joint pinch or retard the swinging of the boom. A back lock makes it impossible for the mast to be lifted clear of the step. The spider is made of buckled plates. The regular set of iron for a guy derrick includes the mast head block, two sheaves in the foot block, one sheave in the mast step, and one sheave in the boom end.

In these controllers the wires and cables are brought to a series of fixed contacts, usually arranged in a straight line.

A series of corresponding contacts are attached to a revolving drum, the various combinations of connections for hoisting, lowering, etc., being obtained by rotating this drum into different positions.

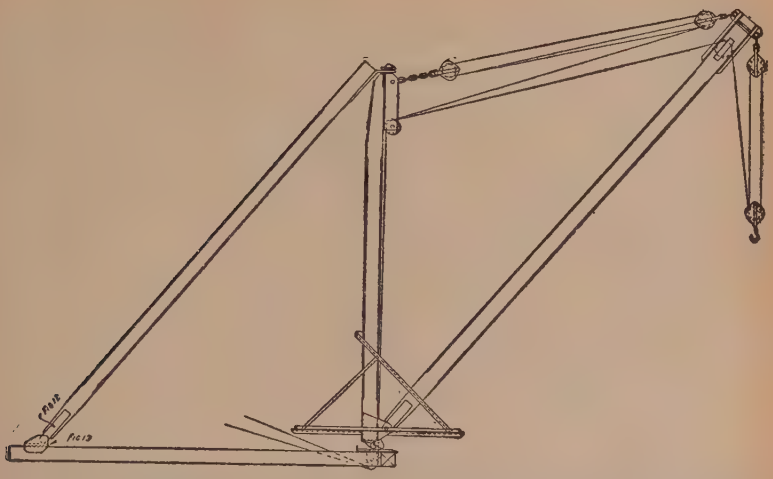
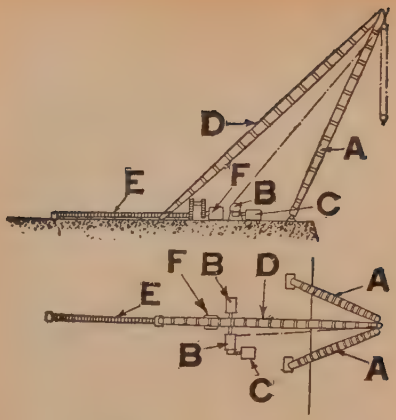
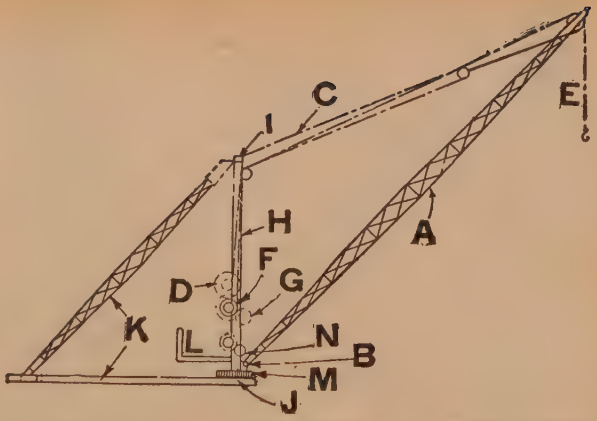


FIG. 6,930.—Stiff leg derrick with bull head and swinging gear. This type derrick has, as its name implies, rigid timbers or "legs" in place of guys. ***In construction,*** the goose neck irons for the stiff legs are made very heavy at the bend and bent close in to the mast top. The back or stiff leg connections to the sills allow the stiff legs to be set at any angle. They require no framing. When it is desired to rig these derricks with the fall line down the boom, one of the mast top sheaves is put in the mast step. The length of the boom should be approximately 1½ times the length of the mast.

NOTE.—***Power required for traveling cranes and hoists.*** Ulrich Peters, in *Machinery*, November, 1907, develops a series of formulæ for the power required to hoist and to move trolleys on cranes. The following is a brief abstract. Resistance to be overcome in moving a trolley or crane bridge. P_1 = rolling friction of trolley wheels, P_2 = journal friction of wheels or axles, P_3 = inertia of trolley and load. P = sum of these resistances = $P_1+P_2+P_3 = (T+L)\left(\frac{F_1+F_2 d}{D}+\frac{V}{1{,}932t}\right)$ in which T = weight of trolley, L = load, F_1 = coefficient of rolling friction, about .002 (.001 to .003 for cast iron or steel); F_2 = coefficient of journal friction, = .1 for starting and .01 for running, assuming a load on brasses of 1,000 to 3,000 pounds per square inch; (F_2 is more apt to be .05 unless the lubrication be perfect); d = diameter of journal; D = diameter of wheels; V = trolley speed in feet per minute; t = time in seconds in which the trolley under full load is required to come to the maximum speed. Horse power = sum of resistances × speed in feet per minute ÷ 33,000. Force required for hoisting and lowering: Fh = actual hoisting force, F° = theoretical force or pull, L = load, V = speed in feet per minute of the rope or chain, c = hoisting speed of the load L, c ÷ V = transmission ratio of the hoist, e = efficiency = $F^\circ \div F^h$. The actual work to raise the load per minute = FhV = Lc = $F^\circ V \div e$. The efficiency e, is the product of the efficiencies of all the several parts of the hoisting mechanism. such as pulleys, windlass, gearing, etc. Methods of calculating these efficiencies, with examples, are given at length in the original paper by Mr. Peters.



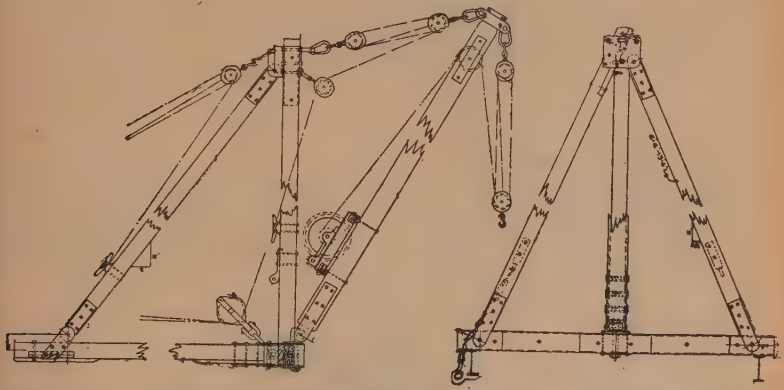


FIGS. 6,931 and 6,932.—Sheer legs. This is a type of lifting appliance used for handling extremely heavy loads such as ship's boilers and heavy guns. The load rope passes over a pulley at the head of the legs A, and is led to the winding drum B, which is driven by the motor C. The bottom of the back leg D, is traversed by a screw E, driven by the motor F, so as to traverse the load in or out. Occasionally a second hoisting drum and motor are provided to handle light loads at quick speeds. It will be noted that with this type of crane loads can only be picked up and deposited along a horizontal line which is a continuation of the center line of the screw.

FIG. 6,933.—Electric derrick crane. The load hangs from the end of the jib A, which is supported by the pin B, and rope C, which leads to the jibbing drum D, by which the jib can be lowered. The load rope E, is led to the drum F. Drums D and F, are driven by motor G. A clutch is provided by which the drum D, may be put in or out of gear with drum F. When D, is out of gear, the drum F, is used to lift or lower the load. When the two drums are clutched together they run in opposite directions, so that when drum D, is hoisting the jib, drum F, pays out the load rope, and vice versa. Thus, whether the jib is being lifted or lowered, the load remains steady, and simply runs in or out in a horizontal line. The jib and the motors and gearing are carried by the vertical mast H, which turns in bearings I, J, in the framing K. The driver's platform L, is also attached to the mast, and the various controlling switches and levers are placed on this platform. To slew the mast and jib, a toothed wheel M, is fastened to the framing and gearing. With this is provided a pinion, the shaft of which is carried in bearings on the mast, and is driven by the slewing motor N. This type of crane will serve an area having a radius equal to the maximum horizontal radius of the jib, and forming a segment of a circle embracing an arc of rather less than 270 degrees.

Derricks.—By definition a derrick is *an apparatus for lifting and moving heavy weights*. It is similar to the crane, but differs from it in having the boom, which corresponds to the jib of the crane, pivoted at the lower end so that it may take different inclinations from the perpendicular.

The weight is suspended from the end of the boom by ropes or chains that pass through a block at the end of the boom and thence directly to the *crab*, a winding apparatus or motor at the foot of the post. Another rope connects the top of the boom



FIGS. 6,934 and 6,935.—Jinniwinks or so called "A" frame derrick. This differs from the ordinary stiff leg derrick in that it has in place of a boom, two inclined timbers, fastened to a horizontal cross piece and a stiff leg fastened to a second horizontal member projecting backward at right angles with the first. It is thus made with the minimum amount of framework, thus securing lightness with resulting ease of moving and erecting as well as security and rapidity of anchoring down.

with a block at the top of the post, and thence passes to the motor below.

The motions of the derrick are:

1. A direct lift;
2. A circular motion around the axis of the post;
3. A radial motion within the circle described by the point of the boom.

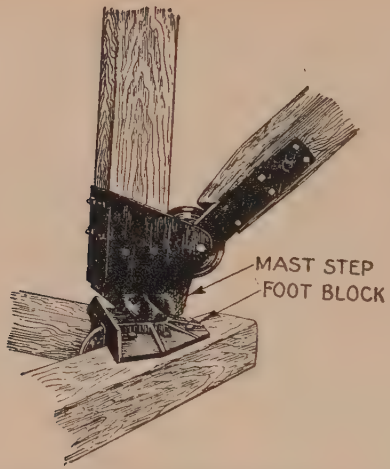
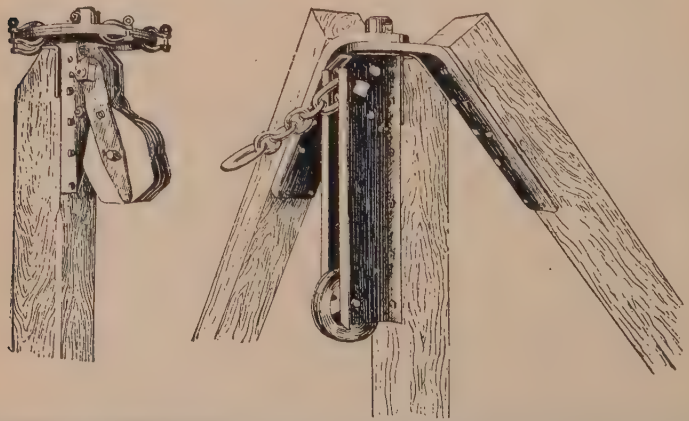
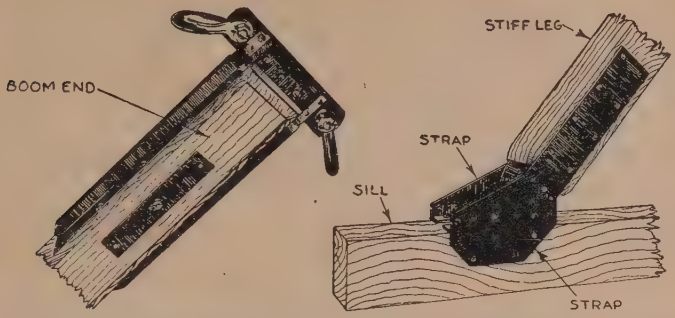


FIG. 6,936.—***Derrick fittings:*** 1. *foot block and mast step irons*, showing lock at the rear of the ball and socket joint. There are two sheaves in the foot block and one in the mast step. The sheave in the mast step is not required for stiff leg derricks. Special foot blocks and mast steps are required for handling clam shell or orange peel buckets and other three line work.

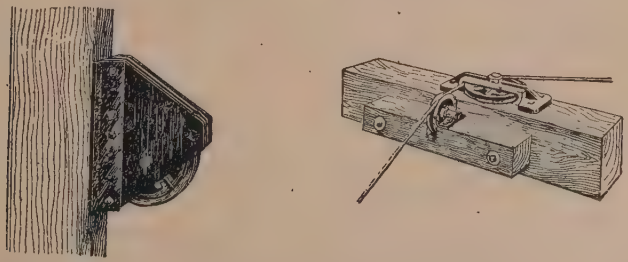


FIGS. 6,937 and 6,938.—***Derrick fittings:*** 2. *mast top irons*. Fig. 6,937, irons with spider plate for guy derricks; fig. 6,938, irons with goose necks for stiff leg derricks. Iron cone complete with block, pin, shackles, back plate and bolts as shown.



FIGS. 6,939 and 6,940.—***Derrick fittings:*** 3. *boom end* for general work and *stiff leg connection* to sill with stiff leg straps.

FIGS. 6,941 and 6,942.—***Derrick fittings:*** 4. *boom idler* for guy derricks and *boom end* for operating clam shell or orange peel buckets. The hole on lower side is for a shackle pin which can be used to attach upper block for a fall with several parts.



FIGS. 6,943 and 6,944.—***Derrick fittings:*** 5. *mast brackets* used with derricks operating clam shell and orange peel buckets, and *guide sheaves* for bull wheel line.

On shipboard a derrick is a spar raised on end, with the head steadied by guys and the heel by lashings and having heavy weights. The accompanying illustrations show various types of derrick in general use.

Telpherage.—This word is defined as: *Automatic aerial transportation as by the aid of electricity, especially that system in which carriages having independent motors are run on a stout wire conducting an electric current.*

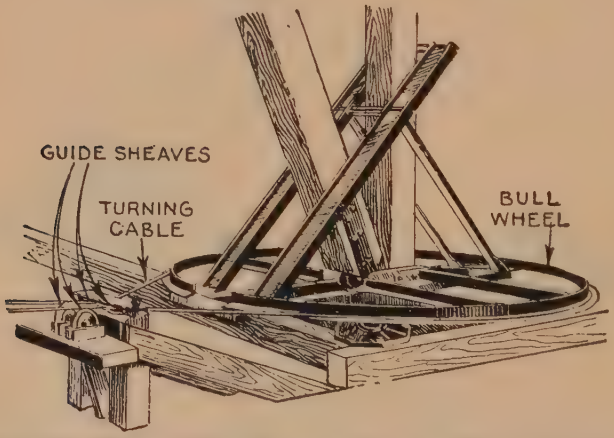


FIG. 6,945.—***Derrick fittings:*** 6. bull wheel and guide sheaves. The wheel is made in halves and may be conveniently erected without unstepping the mast. The ring is a heavy angle iron with the vertical leg rolled with an appreciable outward flare which eliminates any tendency for the line to climb. An inverted movable section of the ring is placed under the boom which makes it a full circle. The braces which drive the boom are made of steel beams, and sills of heavy angles.

Telpherage is a name introduced by the late Professor Fleeming Jenkin to designate a system devised by him, by which the transmission of a vehicle by electricity to a distance is effected independently of any control exercised from the vehicle; it is an aerial electric railway.

Telpherage properly includes those systems employing a wire or cable for a track, but the term is erroneously applied to systems using a rail.

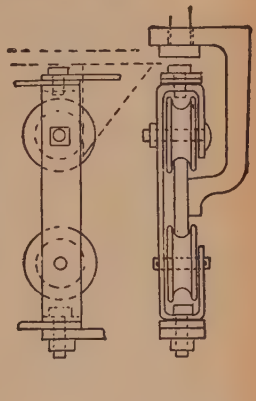
There are two divisions of telphers:

1. Automatic;
2. Non-automatic.

The automatic type comprises those *which are driven by electric motors, the control being a part, or remote from the telpher.*

The original telphers were automatic, the telpher being placed in the middle of the train. They are employed for handling coal, ore and bulk material.

Non-automatic telphers are those *which are controlled by an operator who travels with the load and who operates both the telpher*



FIGS. 6,946 to 6,948.—Delta continuous trolley system.

and hoists from a cab or case which is attached to the telpher or carriage.

Non-automatic telphers are employed for bulk material, like the automatic telpher, and are also used for the hoisting and conveying of miscellaneous material, boxes, cases and barrels, the package freight of railways and the mixed cargoes of steamships.

A telpher is suspended from one or more wheels in tandem, of which one or all are driven by the electric motor or motors.

In the minimum head room two ton type designed for railway and steam ship terminals the vertical space from the underside of the roof girders to the bottom of the hoist hook is 4 ft. 9 in. (144.8 cm.). The width of the hoist is 3 ft. 3 in., and 4 ft. 8 in. to the limit line for 10 degrees swing. From the center of the rail to the inner limit of the telpher and hoist is 16 inches.

Energy in the form of either direct or alternating current is communicated to the motors by conductors which lie parallel with the track, the contact being made by shoes or wheels.

Sometimes storage batteries suspended from the telpher or the carriage are employed. On steep grades the telpherage traction, in some installations, has been assisted by supplementary cables, either fixed or movable.

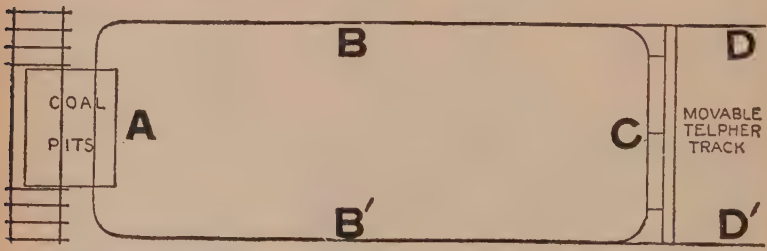


FIG. 6,949.—Typical arrangement of mono-rail tracks. The track is supported on brackets attached to buildings, or is supported on A bents. Supports under straight track are spaced 20 feet apart, and on curves, the spacing is 8 feet. For long spans, cables or trusses are used. The tracks may be either fixed or movable. ***In the figure,*** the side tracks BB′, are fixed, but C, is movable, being attached to a traveling bridge. The speed of this bridge is from 300 ft. to 900 ft. per min. The motor driving this bridge would have a load factor of .16. The telpher train is passed from these side tracks B′, by means of a gliding switch upon the movable track C. This track therefore may be placed anywhere over the area between the fixed side tracks. The telpher returns by means of the track B′, to its starting point A. By the operation of this movable track all the spaces can be served; this operation is called transferage. The minimum allowable radius of curves is 8 ft.

Telpher Motors.—The sizes of motor for telphers and hoists will depend upon the class of work to be done; the motors for telpher tractors vary from 5 to 15 *h.p.* and for the hoists, from 3 to 75 *h.p.*, the loads being from 500 lbs. to 30,000 lbs. The load factor for the tractor motor is .25 and for the hoisting motor .16. The driving wheels and the motors may be

connected by gears or by chain drive. The maximum service efficiency of the motors is that corresponding to the efficiency obtained between one-half and three-quarters full load. The motors are of slow or medium speed.

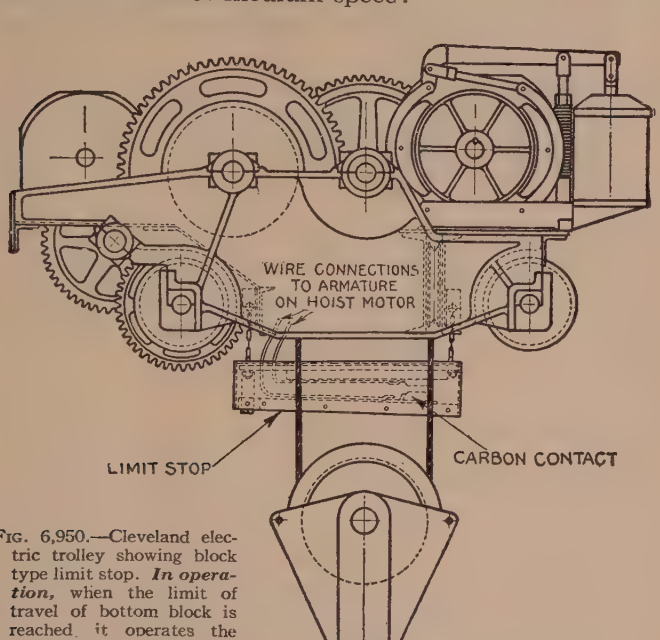


FIG. 6,950.—Cleveland electric trolley showing block type limit stop. ***In operation,*** when the limit of travel of bottom block is reached it operates the limit stop direct and not in connection with something else. To lower, it is only necessary to reverse controller, automatically resetting limit stop.

Direct current 250 volt or 500 volt series wound motors are preferable for tractors and hoists though alternating current motors afford satisfactory results. The motors should be dust and weather proof, and should have a 50 per cent. reserve in their rating. The average combined efficiency of the motors and gearing, for the tractor and hoist, is from 65 per cent to 75 per cent.

Brakes.—The mechanical type of telpher brake is used and the hoist brake is of either the electro-mechanical or electro-dynamic types. Spur gears and chain drive on the tractor transmit the power from motor to track wheels, and either spur or worm gear is used to transmit power to the hoisting drum.

Trackage.—Telphers either run in one direction on a closed track circuit, or to and fro over a single line. On the single line the automatic telphers reverse themsleves on completing their trips.

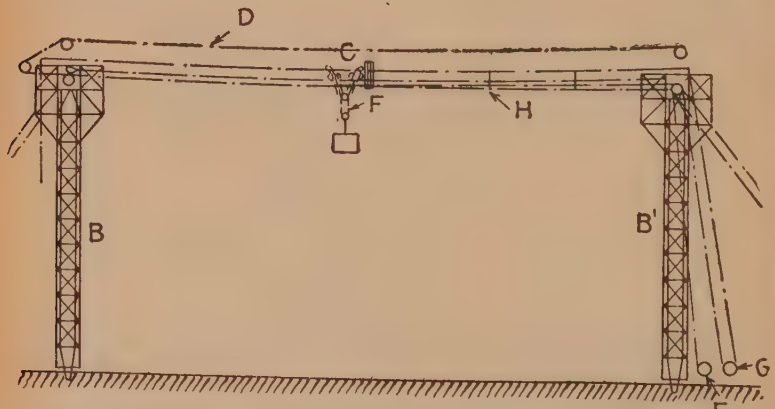


FIG. 6,951.—Cableway. The essential elements of construction are BB', towers; C, cable; D, hauling rope; E, hauling rope drum; F, hoisting rope; G, hoisting drum; H, hoisting rope slack carriers.

Essentials of Cableways.—The term cableway may be defined as a rectilinear *hoisting and conveying apparatus supported by a cable.*

The elements of construction are shown in fig. 6,951. A strong steel wire rope or cable is stretched between the towers BB'. On this rope runs the carriage C, pulled backward and forward by the hauling rope D, which is operated by the capstan drum E. One end of the hoisting

rope F, is secured to the carriage, and is led round the various pulleys shown and to the hoisting drum G.

The slack of the hoisting rope, when paying out, is supported by the carriers H. These carriers are dropped by the carriage when running from B to B′, and are picked up again when returning from their position, being determined by buttons of different size arranged on the rope. Loads are hoisted and lowered by drum G, driver E, being held by its brakes.

To travel the load, the two drums are clutched together. Driver E, then hauls the carriage along, while drum G, takes in or pays out the hoisting rope, so that the vertical position of the load is unaltered.

A cableway will take up and deposit loads anywhere along a line directly underneath the main cable, and by means of switch blocks it may be made to serve an area having a width of about 15 feet or so each side of the cable.

TEST QUESTIONS

1. *Give definition of a crane.*
2. *How are cranes classified?*
3. *Describe the various types of crane.*
4. *What are the essentials of the rotary crane?*
5. *What is the most economical position of the inclined brace in a jib crane?*
6. *What are the features of rectilinear cranes?*
7. *Make a sketch of an electric traveling crane.*
8. *What are the essentials of combined rotary and rectilinear cranes?*
9. *What is a transporter?*

10. *How long does it require a transporter to complete a cycle of operation?*
11. *What are the requirements for crane motors?*
12. *How is the power required to drive cranes determined?*
13. *What is the friction allowance for cranes in power calculations?*
14. *What is the most important consideration in selecting motors?*
15. *Describe the construction of automatic electro-magnetic brakes.*
16. *How is the coil of the brake solenoid connected?*
17. *What is the usual type of automatic mechanical brake?*
18. *How is the automatic mechanical brake released?*
19. *Are eddy current brakes extensively used?*
20. *How is the controller arranged for rheostatic brake?*
21. *Describe the method of regenerative control.*
22. *How is the collector gear arranged?*
23. *Describe the term* telpherage.

CHAPTER 161

Lifting Magnets

Lifting magnets are used in connection with power operated cranes and hoists, for lifting magnetic material, especially where such material must be handled in bulk. They are especially useful in and around foundries, steel mills, etc., for lifting such materials as pig iron, metal plates, billets, scrap iron, steel castings, rails, "skull crackers" and, in fact, anything except non-magnetic metals, such as brass and copper.

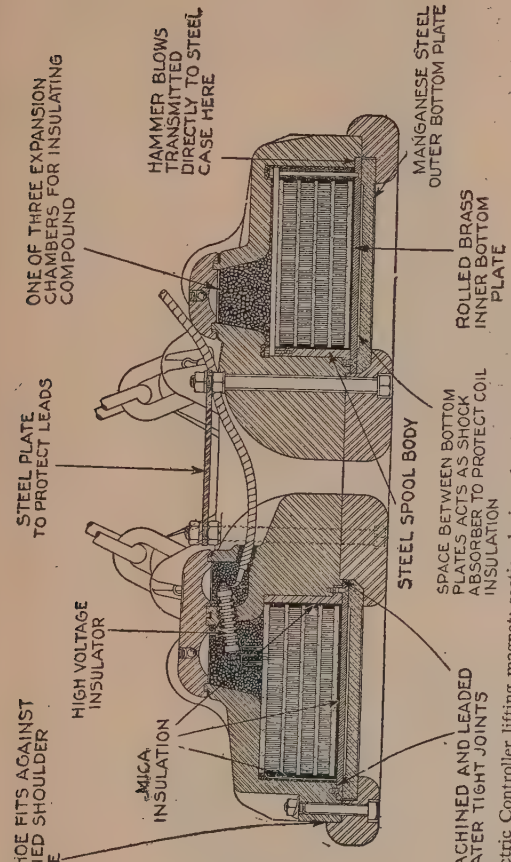
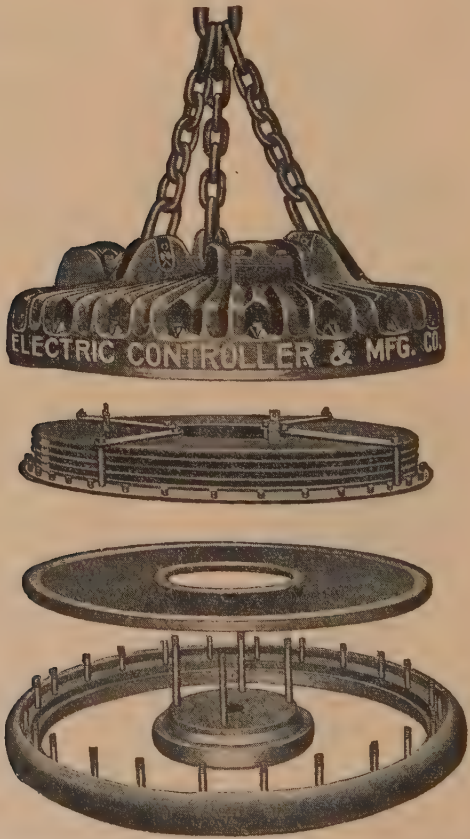


FIG. 6,952.—Electric Controller lifting magnet; sectional view showing construction.

The magnet is energized by *d.c.* and it greatly facilitates handling material of the classes mentioned, because the parts to be lifted are easily gripped or released by the magnet and quite a number of pieces can be lifted at one time, especially in the case of small billets, plates, etc. No time is required for adjusting hoisting tackle to the part or parts to be lifted, and



FIGS. 6,953 to 6,956.—Electric Controller lifting magnet disassembled showing coil wound on spider, outer bottom plate of manganese steel and renewable pole shoes held with through bolts.

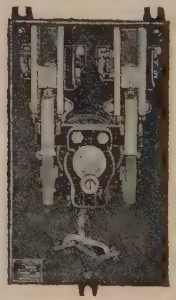
FIG. 6,957.—Electric Controller lifting magnet. View showing separate terminal boxes for each lead and ribbed housing.

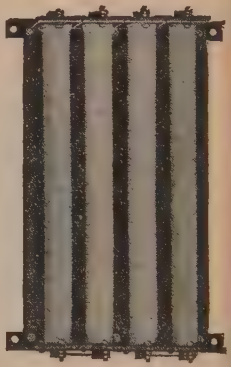
FIG. 6,958.—Electric Controller lifting magnet showing bottom plate to render the magnet moisture proof. The inner brass bottom plate hermetically seals the coil cavity.

in handling pig iron, scrap, etc., the parts to be moved need not be arranged in piles.

All that is necessary is to lower the magnet onto the material, switch on the current and transport the magnet with its load by means of the crane to the place where the material is to be deposited.

In foundries, blast furnaces, and rolling mills, magnets are often used for lifting and transporting metal which is too hot to be touched with the hands.





FIGS. 6,959 to 6,961.—Electric Controller lifting magnet control device. It is of the contactor type and provides for quick release of the load and for safety to the operator as he handles only the lever of a small master switch which controls a double pole magnetic contactor, which in turn opens and closes the circuit to the lifting magnet. The contactor is designed to break the highly inductive arc with minimum wear on the contacts. A resistor is supplied for limiting the flow of reverse current in the "drop" position. The master switch should be mounted conveniently for the operator but the magnetic contactor and resistor may be located at any distance from it. When operating the magnet, the master switch lever is moved to the lift position after the magnet has been lowered on to the stock pile. Two or three seconds should be allowed to permit the magnetism to build up to full strength before hoisting the load. To drop the load, the lever is moved to the drop position. The load is at once released and the lever should then be returned to the off position and left there until the magnet is again lowered onto the stock pile.

Classification.—There are several types of magnets, classified according to the nature of the material for which they are designed to lift.

1. Pig magnets.

For material of irregular shape, piled indiscriminately.

2. Plate magnets.

For lifting straight shapes from orderly piles.

3. Bi-polar magnets.

For handling irregular and regular shapes.

4. Special magnets.

Designed for some special class of material.

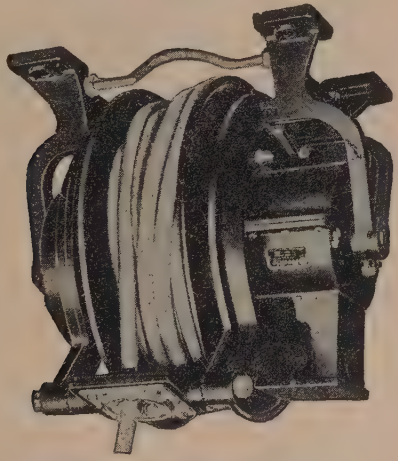


FIG. 6,962.—Electric Controller lifting magnet rope take-up. Spring operated rope reels of the type illustrated are recommended for keeping the magnet rope taut. The reel pays out and winds up the rope keeping the correct tension on it at all times. These reels will accommodate from 40 to 150 ft. or more duplex rubber covered flexible magnet rope.

Pig Magnets.—This type is provided with a central cylindrical pole and a concentric outer pole, with a magnetizing winding inserted in an annular slot or space between the two poles. These magnets are designed to give fields of deep penetration by reason of the powerful magnetizing winding and wide spread poles.

Plate Magnets.—For this service the magnet is rectangular in shape and has two parallel outer poles of like polarity, and a common central pole on which is wound the magnetizing coil. This type of magnet is designed to give a field of small penetration, the magnetizing winding being relatively less powerful, the poles closer together, and the steel section lighter than in the case of a pig magnet.

The lifting capacity per inch of face, in contact with a single layer of material not less than 1¼ in. thick, is 500 lbs.

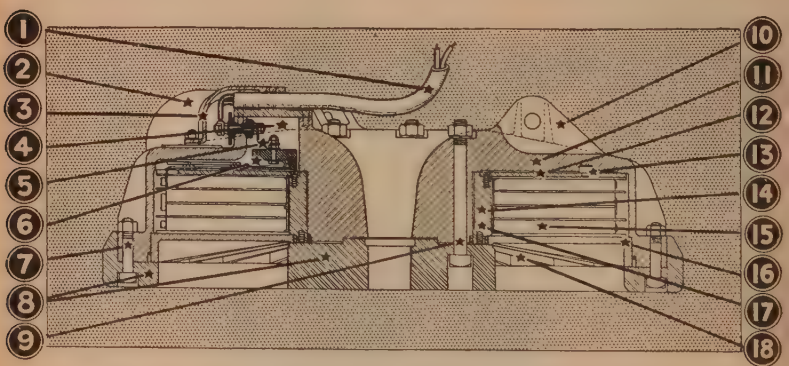
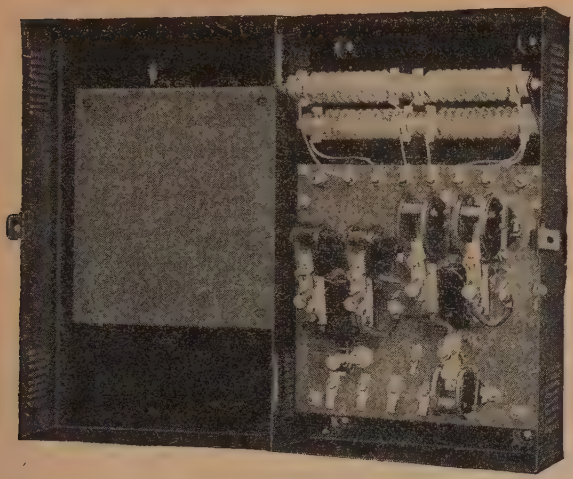


FIG. 6,963.—Cutler Hammer lifting magnet sectional view showing construction. ***The parts are:*** 1, leads, protected by 5 ft. of steam hose; 2, protecting flange for terminal box; 3, terminal hood; 4, terminal cavity; 5, coil terminal studs; 6, flanged outer pole shoe; 7, heat treated alloy steel through bolts; 8, inner pole shoe; 9, through bolt; 10, suspension lugs; 11, magnet case; 12, top plate of coil spool; 13, dowel; 14, core of spool; 15, magnetizing coil; 16, coil shield; 17, tapped eye bolt hole; 18, heavy protecting ribs.

Bi-polar Magnets.—This type, sometimes called *rail magnet* usually consists of a pair of vertical triangular shaped poles connected by a horizontal yoke which carries the magnetizing winding. Magnets of this type are adapted principally for handling plates and straight shapes but as they have a much deeper penetration than plate magnets, they can also be used for handling miscellaneous materials, such as pig iron and scrap iron; hence, bi-polar magnets are used in cases where the



FIGS. 6,964 and 6,965.—Cutler Hammer lifting magnet controller and master switch. To protect the operator and equipment from the hazards of high induced voltage, provision must be made in the controller to keep the voltage down to a safe value. This can be done only by providing a circuit in which the coil energy can be dissipated. The control system is designed to keep the voltage low, and a reverse connection is provided to expedite demagnetization and cause quick release of the load. When the master switch handle is moved to the off position, the magnet discharge voltage is kept low by shunting a low value of resistance in two parallel paths across the magnet terminals by means of a lower contact on the magnetic lift switch which closes at the same instant the upper contact opens the magnet circuit. As the operator moves the master switch handle to the drop position, the drop switch closes, thereby opening its lower contact and closing its upper contact. The opening of the lower contact opens one of the two parallel discharge paths, leaving the other to prevent high induced voltage. The closing of the upper contact provides a reverse circuit to the magnet. The upper contact on the lift switch is open only $\frac{1}{16}$ in. when the lower contact touches. This keeps down the arc when the circuit opens. Even when the circuit is opened accidentally, such as a trolley jump, the switch drops open and provides a discharge circuit so quickly that the induced voltage is not high. The correct proportioning and connection of resistors protects the operator, the magnet, the controller and all interconnected equipment by keeping voltages low. The new lifting magnet controller automatically reverses current momentarily when load is dropped.

NOTE.—The master switch (fig. 6,965) carries only the pilot current controlling the magnetic switches. The lines to the magnet are not connected to the master switch. It has three positions—lift, off and drop, marked on the brass indicating plates. In the lift position, the lift switch is closed, connecting the magnet across the power lines. In the off position, both magnetic switch coils are out of circuit and the magnet discharge circuit is made. In the drop position, the drop switch is closed, reversing the circuit through the magnet. A spring return is provided from the drop position to off so that the magnet will not be left in circuit accidentally.

principal work consists of handling straight parts and where it occasionally is necessary to handle pig or scrap iron.

The bipolar or rail magnet has been used extensively for handling rails, pipes, billets, structural materials, and in general, straight pieces of considerable length as compared to the width and thickness. This type has been exploited as the rival of the circular pig magnets, but the results of tests do not seem to indicate its superiority for general work.

In general, however, it cannot compete with the circular type; besides being of smaller capacity, its shape makes it liable to incur very severe torsional strains which are liable to prove detrimental to its life. It has also been found very liable to stick to the sides and bottoms of steel cars on the clean up lifts.

Lifting Capacity of Magnets.—The weight that a magnet of given size can lift depends upon the form of the material and the evenness of the surfaces which must be gripped by the magnet. It might be possible to lift 20,000 lbs. or more, under favorable conditions, and only 1,000 lbs. or less, under adverse conditions, the same magnet being used in each case.

For instance, when there is a solid mass of steel or iron and a surface which affords a good magnetic contact, naturally, a much greater weight can be lifted than when there are a number of pieces which not only cling to the magnet but to each other, or in case the material is of such a form that a comparatively small surface is in contact with the magnet poles.

TEST QUESTIONS

1. *Name the various uses made of lifting magnets.*
2. *What kind of material cannot be handled?*
3. *Give a classification of lifting magnets.*
4. *Describe a pig magnet and a plate magnet?*
5. *What is the construction of a bi-polar magnet?*
6. *What is the lifting power of magnets?*
7. *Upon what does the lifting power of magnets depend?*

CHAPTER 162

Electric Trucks and Tractors

By definition, electric powered trucks and tractors are motor operated vehicles used as a means of material conveyance within or in close proximity to industrial plants or warehouses.

The power plant generally consists of a lead-acid or nickel-iron alkaline battery, whose energy is converted into mechanical form by means of electric motors, usually of the series-wound direct-current type.

For small trucks, the motor voltage is seldom under 12 volts, corresponding to the battery voltage. In large trucks the number of battery cells in series is increased, with a consequent increase in voltage in the order of 12, 24, 32, 40, 48, 60 or 72 volts.

This increase in voltage with each increase in horse-power requirements keeps the load current more nearly constant for all sizes of trucks, than would be the case if voltage were kept constant with an increase in power requirements.

Industrial trucks are usually equipped with a suitable platform or fork carriage for storage of material to be transported, whereas tractors are commonly furnished with a draw-bar and coupling arrangement permitting one or several trailers to be attached to the motor powered vehicle.

Classification.—Although there are a great variety of industrial trucks and tractors available for transportation of various types of material and handling methods, they are usually classified as:

1. Tractors.

2. Platform trucks (elevating and non-elevating).

3. Fork trucks.

4. Powered hand trucks, etc.

The industrial tractor is used to pull trailer trains or push loads. The three-wheel tractor, with its small turning radius, can work in crowded aisles and pass through narrow doorways. Larger four-wheel tractors haul heavier loads and are more often used in yards and inter-plant haulage. The tractor is most economical in hauls of more than 300 feet. Tractors can be readily uncoupled from and coupled to, the tractor trains. This avoids tying up motive power while the trailers are being loaded or unloaded. The per unit power cost is lower than that of a power truck.

Non-elevating platform trucks are used for carrying baggage, ice, and other miscellaneous loads particularly at railroad terminals. They must be loaded or unloaded manually or by other equipment.

Low-lift platform trucks are used to lift skid loads only a few inches in order to move them from place to place. They are not designed for stacking loads.

The high-lift platform truck is commonly used for tiering skidloaded materials. It is less versatile than the fork truck because the skid requires more vertical space. It can however,

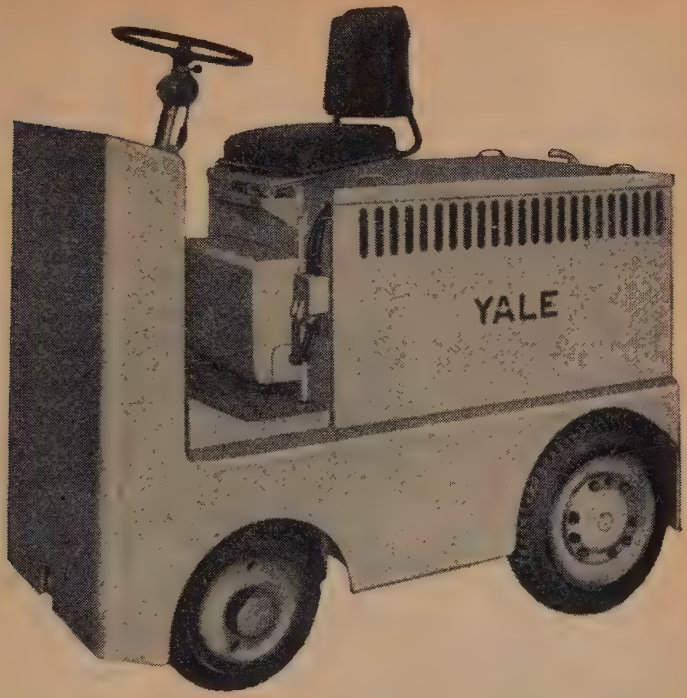


FIG. 6,966.—Typical tractor employed for hauling of material in industrial plants. Tractors of this type may be equipped with two or four wheel drive as required.

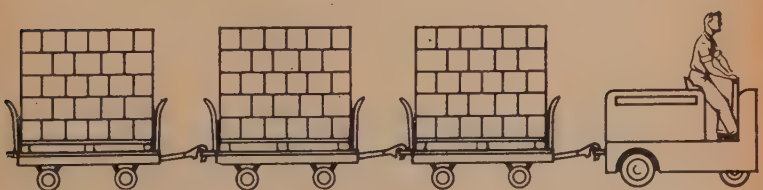


FIG. 6,967.—Illustrating typical tractor train. This method of haulage is commonly used in inter-plant material handling where economy and flexibility is a factor of consideration.

handle heavier loads than a fork truck of the same weight because its weight is centered.

The fork truck is generally used with the *pallet system* of material stowage and movement, and is most economical for transporting pallet loads for relatively short distances. Long horizontal distances keep the lifting equipment tied up too long for economy.

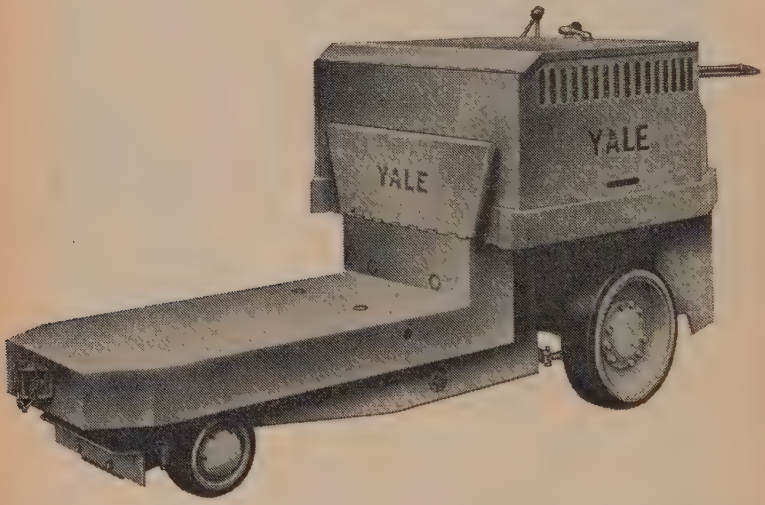


FIG. 6,968.—Typical low-lift platform truck. Low-lift platform trucks are designed to handle skid platforms, skid bins and so on. Easy and safe to operate, these trucks move great tonnage, increase handling efficiency, speed production and cut costs.

The powered hand truck is an economically priced substitute for the larger, heavier fork truck or platform truck, but in most cases makes slower handling. It is useful in confined spaces because it is small, being used extensively to load and unload box cars.

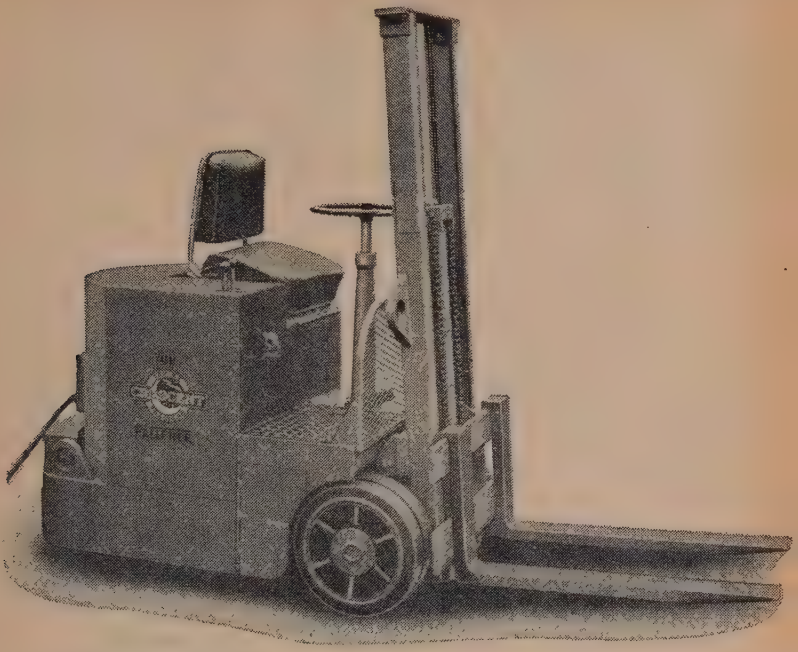
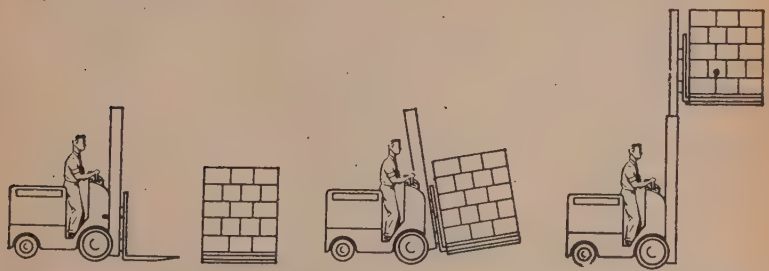
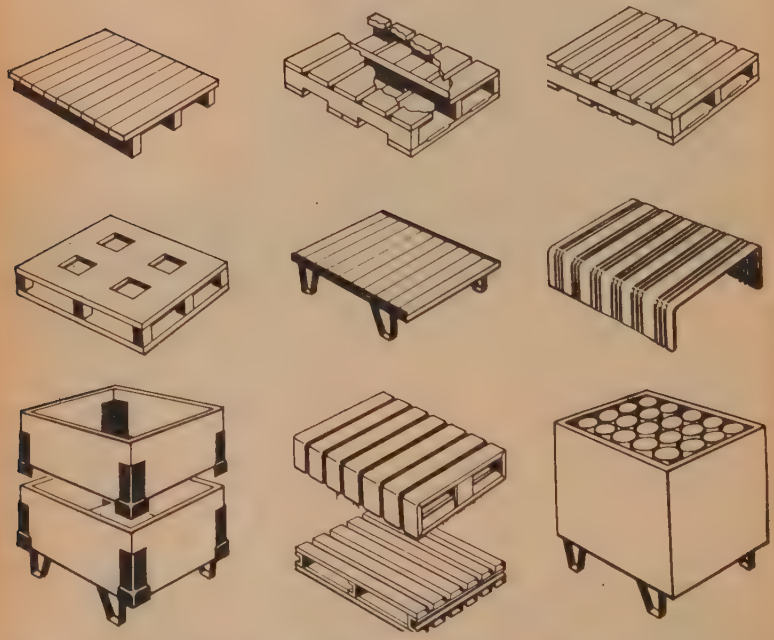


FIG. 6,969.—Illustrating typical fork truck. This type of power industrial truck contains within itself a means of picking up, transporting and stacking of pallet loads without the need of manual or other external handling.



FIGS. 6,970 to 6,973.—Showing step-by-step method of pallet load material handling using a fork truck.

Powered hand trucks are designed to handle either skid or pallet loads. Some are suitable for hoisting and stacking. Their light weight is another important advantage. Controls in the steering handle are used for forward and reverse motion. The mechanism for raising and lowering the load is usually controlled by a foot pedal.



FIGS. 6,974 to 6,983.—Illustrating various types of pallets and skids for various types and methods of material handling. The economic advantages of handling unit loads with fork and platform lift trucks have led to the development of a large variety of pallets and unit load containers, some of which have been standardized as to size and unit strength.

Motors.—For electric vehicles, these are in all respects quite similar to electric railway motors, except that they are designed to operate safely at an overload of 300 per cent or more to enable the heavily loaded vehicle to pass a steep incline or upgrade, so that in spite of their low power rating they yield a high percentage of efficiency and are capable of operating under several different voltages and a number of different speeds.

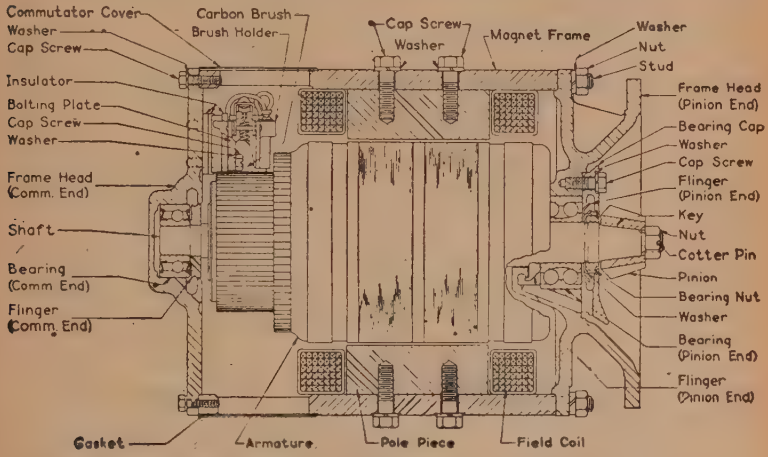


FIG. 6,984.—Sectional view of traction motor used in electric powered trucks and tractors.

Each electrically operated lift-truck is equipped with two series-wound direct current motors, that is:

1. Traction motor, and

2. Pump motor.

The traction motor is usually of the split-field four-pole type, that is the field coils are connected in pairs, each pair having two leads brought out through the motor frame making a total

of six leads from the motor, that is, two armature and four field leads.

Electrical Equipment.—The equipment controlling the movements of an electrically operated truck in addition to the power source and motors are:

a. A combined motor controller and reversing contactor.

b. A high capacity line contactor.

c. A motor accelerating resistor.

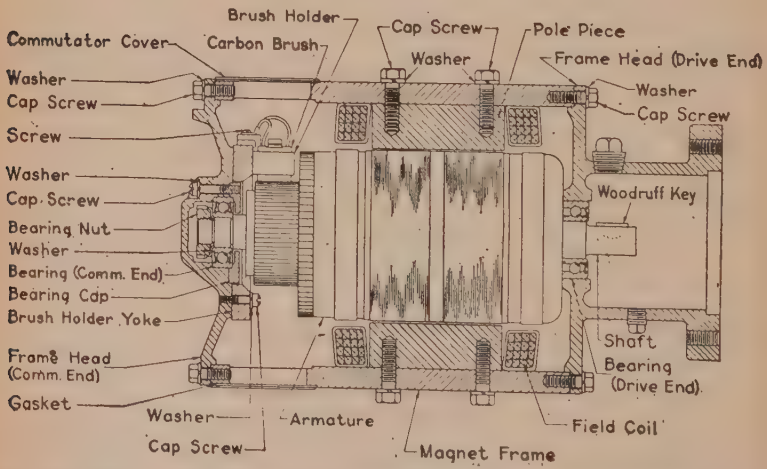


FIG. 6,985.—Sectional view of pump motor used in hydraulically operated lift truck. The hydraulic system consists essentially of a set of hoist cylinders, a tilt cylinder and a packaged power unit.

The hoist and tilt operations on lift trucks are usually hydraulically operated. The power for these operations is supplied by a series-wound pump motor with a contactor (similar to

the line contactor for the traction motor) for making and breaking the connection from the battery to the pump motor as required.

The traction motor armature leads are connected to the reverse contactor so that the change in direction of rotation is accomplished by reversing the armature connections.

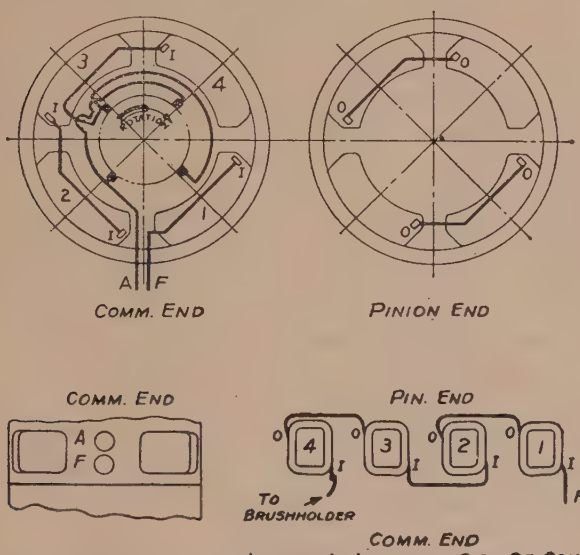


FIG. 6,986.—Electrical connections for typical series-wound pump motor.

The use of the split field motor permits the motor to be operated with all four field coils connected in series while starting the truck or climbing grades, and with the field coils connected in series-parallel for high speed running.

When operated in this manner two running speeds are provided on which there are no resistor losses. For starting purposes, two additional points of control are obtained by means of an accelerating resistor.

Battery Charging Equipment

Because of the fact that any battery is only a means of storage for electrical energy, its proper operation requires frequent charging with direct current of special characteristics. Since alternating current is nearly always the only industrial power supply available, conversion equipment between the alternating current power supply and the battery terminals is necessary.

There are several types of battery charging equipment commonly employed. They are:

1. Motor-generator sets with special control.
2. Rectifier (Dry plate or electronic type).
3. Direct current (Power circuit resistors).

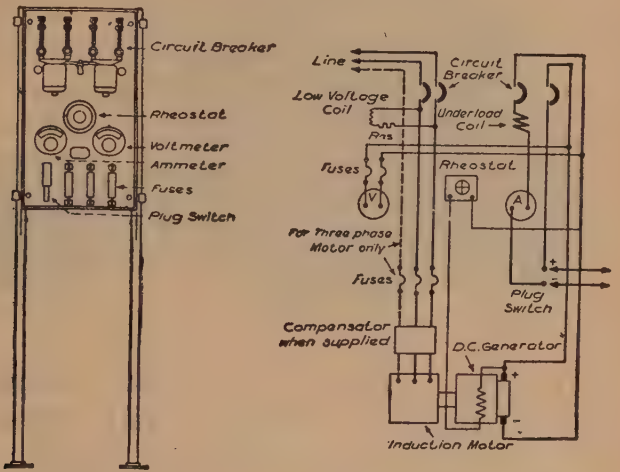
The third method, which is very seldom used, is not only wasteful of power, but in addition does not provide the constant voltage regulation that is of the utmost importance in charging operations.

Selection of the correct charging equipment depends upon the type, make and rating of the battery used, and the type of electric power available. These factors, together with the number of batteries to be charged simultaneously, will determine the size and type of battery charging equipment that will be required.

Motor-Generator Set vs. Rectifier.—Whether a motor generator or rectifier is used will depend upon local conditions and personal preferences. In general, however, the motor generator set chargers are used for most multi-circuit installations.

Rectifier chargers are commonly used on single-circuit installations, particularly where the batteries are of 12 cells or smaller size of the lead-acid type, or 15 cells or smaller of the nickel-iron-alkaline type.

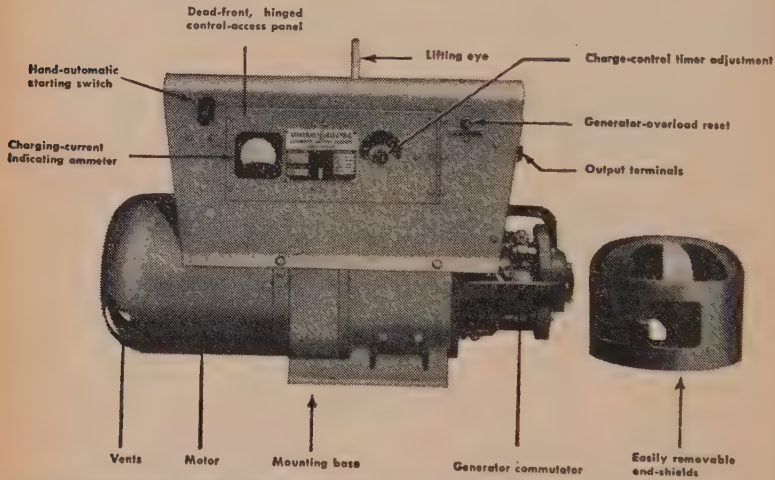
The operating and maintenance cost of both are very nearly equal and both are employed extensively in battery charging of industrial electric trucks and tractors.



FIGS. 6,987 and 6,988.—Showing panelboard and wiring arrangement of motor-generator set in manual method of battery charging.

Space Requirements.—The maximum number of batteries to be charged at one time determines how much floor space should be devoted to battery charging. Thus, for example, if no trucks be operated more than eight hours out of twenty-four the number of batteries will ordinarily be the same as the number of trucks and the batteries may remain in the trucks while being charged.

When batteries are charged in the trucks, wall outlets are spaced so that the trucks can be placed side by side in a row. When there are spare batteries, the charging room may be laid out to provide space for the batteries in addition to that required for battery exchange.



FIGS. 6,989 and 6,990.—Fully automatic motor-generator set adaptable to both lead-acid and nickel-iron alkaline type of batteries.

A wide latitude is possible in the arrangement of the charging equipment. Single and multiple circuits are available for charging either one or a number of batteries simultaneously. Facilities may be made to allow for increased space requirements to keep pace with an increase in the number of trucks or in the number of batteries per truck. In this manner a variable number of batteries may be charged at any one time with the highest possible operating efficiency.

Battery Charging from Motor-Generator Set.—Battery charging equipment must be tailored to fit the battery and must provide the voltage and charging rate which the battery re-

quires. The motor-generator type of charging equipment fulfills all requirements from this point of view regardless of the number of batteries to be charged and irrespective of their size.

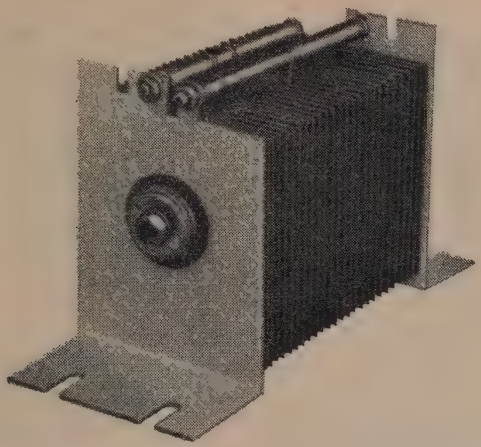


FIG. 6,991.—Typical copper-oxide stack used in storage battery rectifier chargers.

The motor-generator type of charging equipment consists of the following three elements:

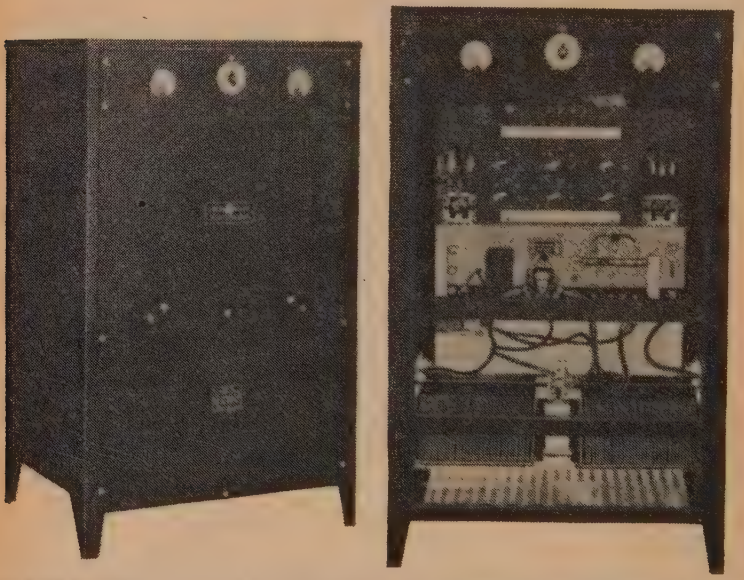
a. Motor-generator set.

b. Motor starter.

c. Automatic charging cubicle.

The direct current generator of the motor-generator set must be designed to have a voltage and current output suited for the batteries which it is to charge. It must also have a 6 percent voltage regulation to insure proper charging rates for the batteries in question. The foregoing characteristics are provided by

a special design of a flat-compound-wound generator. The driving motor is usually of the induction type or in rare cases a synchronous motor.



FIGS. 6,992 and 6,993.—Views of 3.8 kw. copper-oxide automatic rectifier installation suitable for charging industrial truck batteries. The wiring of this charger includes certain safety features in that in the event of power failure, the charger will automatically cut *off*, and on resumption of power, will automatically resume operation. Also on completion of charge, the charger shuts *off* automatically and the battery is disconnected from the charger. An air operated wind switch, opens the circuit and disconnects the charger if for any reason the ventilating fan is stopped.

The automatic charging control cubicle includes the timing devices necessary for limiting the charge of each battery connected in the charging circuit. The tapering charge rate necessary on each individual battery, whether charged singly or several at a time, is accomplished by placing a specially proportioned resistor in each charging circuit. These resistors, combined with associated automatic control devices, are included in the charging control cubicle. The functioning of the entire equipment is interlocked with a suitable starter for the motor-generator set.

Rectifier Battery Chargers.—Because of the heavy current requirements in this type of service, electronic rectifiers are not commonly used. Dry plate rectifiers such as the copper-oxide or selenium-oxide types on the other hand, are available in the required capacities.

The heart of the copper-oxide battery charger is the copper-oxide stack. The stack consists of copper plates, oxidized on one side and assembled on an insulated bolt. These plates allow current to pass only in one direction, thus converting alternating current to direct current. Since this stack has no moving parts, there is practically no maintenance and nothing to replace.

The advantages of the copper-oxide rectifier in battery charging operations is its low initial cost, low maintenance and low power cost; since the rectifier operates at about 70 per cent efficiency at full load and only slightly less at half load. The copper-oxide battery charger is fully automatic in that, when the charge is completed, it disconnects the charger from its source.

The operation of the charger is simple; the operator simply connects the cable, sets the timer to a pre-determined value and the charging cycle is automatically completed. In addition, this type of charger is easy to install, is portable and occupies a small floor space.

When installing rectifiers, it is necessary to observe certain precautions in order to obtain the maximum of trouble-free service. Thus, for example, they should *not* be installed near radiators or in boiler rooms or in close proximity to any heat producing source. They should be placed in a room having a moderate uniform temperature so as to enable the cooling fan to keep the rectifier stack cool. Rectifiers should in addition, be installed in a clean, dry easily accessible location where they are not subject to vibrations or damage.

Types of Batteries Used.—Both lead-acid or nickel-iron-alkaline batteries are available in a wide range of capacities for industrial truck service.

The lead-acid battery is generally the lowest in first cost, but may easily sustain serious damage if it is charged too long or at excessively high current rates.

The nickel-iron-alkaline battery may have a higher initial cost than the lead-acid battery, but its life is usually greater under similar operating conditions.

Number of Batteries Required.—The number of batteries required for a single truck depends upon the hourly usage per day. An eight hour shift is the average working time for one battery with one charge.

Sixteen hours represents the approximate maximum amount of service obtainable from one battery in one 24 hour day, if there is to be sufficient time to recharge it during the remaining hours of the day.

This fact, together with the design of the truck, determines the number of batteries needed for each truck for a given daily duty cycle. Sometimes severe duty cycles, such as frequent operations, or many up-grades, make it necessary to change batteries during a work shift.

When the daily duty cycle requires more capacity than can be obtained from one battery in a given truck, the work should be divided between two or three batteries.

In this manner, a truck with a 16 hour daily duty cycle might be powered by two 8-hour batteries or a truck having a 24-hour daily duty cycle might be powered by two 12-hour batteries.

Battery Charging Time.—The time required to charge a truck battery that has delivered its rated capacity during a working shift is usually from 7 to 8½ hours. A sufficient number of batteries should be available so that the average number of discharge cycles per battery is not more than 300 per year.

The service life of a battery is determined by the number of discharge periods, and it has been found that batteries operated on not more than 300 cycles per year give the best and most economical service.

This schedule should be kept in mind when laying out a battery charging station since it determines the number of batteries for which service must be provided at one time.

Battery Charging Systems.—There are two charging systems in general use. They are:

1. The "two-rate" charging system, and

2. The taper-charging system.

The *"two-rate" charge*, as the name implies, consists of two average rates. In this method, a high charging rate is provided at the beginning of the charge, while toward the end of the charge, this is automatically changed to a low rate.

In actual operation, both high and low rate is obtained in modern charging equipment by the use of a voltage relay in a rate changing circuit.

When the battery cell voltage rises to approximately 2.37 volts per cell at 77° F. the voltage relay automatically lowers the charging rate. The same voltage relay operating with a time switch can also be used to stop the charge automatically.

Two rate charging is generally used with rectifiers, although it is also used with motor-generators, particularly when the voltage is too high for the taper charge. For dependable day-in and day-out repeat performance, the quality of the voltage relay and time switch is important.

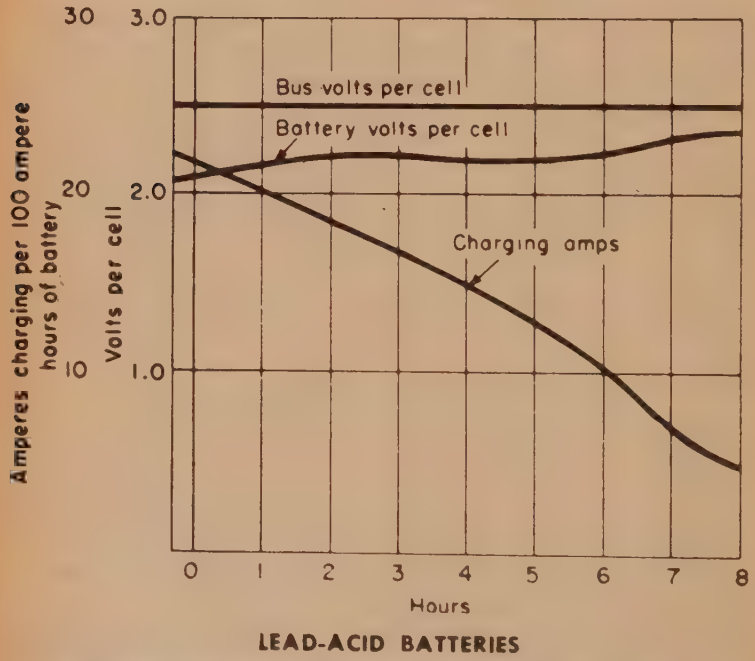


FIG. 6,994.—Charging characteristics of lead-acid storage battery when modified constant-voltage charging method is used.

The *"taper charging"* system also known as the *"modified constant potential method"* of charging, is based on a constant voltage D.C. bus with an especially designed resistor in series with each of the batteries connected in multiple to this bus.

Industry standards of charging current for each type of battery are definitely established and are independent of the make of battery. Resistance values always are included for several values of bus voltage conforming to the requirements of the battery manufacturing industry.

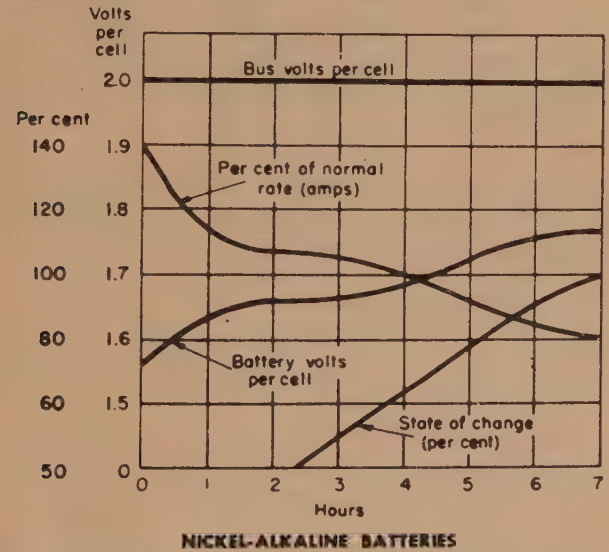


FIG. 6,995.—Charging characteristics of nickel-alkaline battery when modified constant-voltage charging system is used.

It is in this manner of circuit design that the charging voltage source is balanced against the battery voltage rise during the charge. As the battery voltage rises, it approaches the value of the charging source, and hence, there is less difference between the charging source and battery voltage. As a consequence, the flow of charging current will taper off in value opposite to the way the battery voltage rises.

Taper charge requires a close tolerance (plus or minus 3 per cent) of charging source voltage (2.63 times the number of cells) when more than one charge circuit is on the machine. A single circuit taper charge does not need this close voltage limit as the inherent taper is obtained as a natural part of the shunt generator load characteristic.

Taper charge circuits, however, are specifically designed for a definite number of cells in the battery to achieve the inherent taper. The only duty performed by a voltage relay time switch control on the taper circuit is to stop the charge.

Battery Charging Load.—The load imposed on a plants electrical system by battery charging sets, is often of considerable size, and should therefore insofar as possible take place during periods of reduced demands from other power consuming equipment.

This period is usually during the hours of 5 P.M. to 6 A.M. and when so arranged will obviate the necessity for installation of additional generating and associated equipment.

In estimating operating cost of industrial electric trucks, first determine the characteristics of the present electric load. Where the maximum demand is not increased by the addition of the charging load, as is usually the case, the unit cost of electricity required for battery-charging is a small factor in overall truck operating costs.

Battery Maintenance.—An important factor in obtaining the maximum service is to keep the battery clean and dry at all times. Normally wiping the top of the battery with a wet cloth is insufficient.

If the battery be removed from the truck, it can be hosed off with clean water. If an electrolyte be spilled, it will not dry off. Neutralize the acid with a solution of ordinary bicarbonate of soda and rinse throughly with clean water.

A light coating of vaseline or a light cup grease on the terminals will help prevent corrosion on the terminals. If the terminals have become corroded, wash off the corrosion with a soda solution and rinse thoroughly.

Ampere-hour* Capacity	Average High Rate (amperes)	Finish Rate (amperes)		Edison Ave. Rate, (amperes)
		A	B	
150	26– 29	9		30
160	28– 31		8	
170	30– 33	10	8	
190	33– 37	12		38
202	35– 39	12	10	
220	38– 43		11	
227	40– 44	14		45
289	42– 47	15	12	
250	44– 48		12	
265	46– 52	16		53
274	48– 53	17	14	
280	49– 55		14	56
303	53– 59	19	15	61
320	56– 62		16	
330	58– 64		16	
340	60– 66	21	17	68
348	61– 68	21	17	
360	63– 70		18	
374	65– 73	23	19	75
384	67– 75	24	19	
397	70– 77		20	79
408	71– 80	25	20	
421	74– 82	26		
441	77– 86	27	22	
450	79– 88		23	90
460	80– 90	28		
478	84– 93	29	24	
498	87– 97	31	25	
510	89–100	32		
523	92–102		26	105
536	92–105	33		
547	96–106	34	27	
561	98–110		28	112
575	101–112	36		
602	105–118		30	120
613	108–120	38		
640	112–125		32	
650	114–127		32	
660	116–129		33	
677	118–132	42	34	135
689	121–135	43		
700	123–137		35	
715	125–140		36	
750	131–146		37	150
768	134–150	47	38	
800	140–156		40	

*Five- or six-hour rate.
A = Small-sized plates, 34 or 38.3 ampere-hours per positive plate.
B—Medium- or large-sized plates, 34 (Philco), 40, 50, 55 or 100 ampere-hours per positive plate.

FIG. 6,996.—Table showing rectifier charging rate as a function of battery size.

The vent plugs should be in place at all times when using, cleaning, and charging the battery. They should be cleaned weekly by immersing in a bucket of clean water for one half hour. Check the vent holes in the vent plugs and clean out. The vent holes should be open to allow gas to escape from the cell.

The batteries should be numbered and assigned to a given truck. A record should be kept of (1) daily hydrometer reading on a pilot cell at the beginning of each charging. (2) Weekly reading of the pilot cell after charge and (3) a hydrometer reading of all cells and temperature of one cell each month before and after charging. When battery shows non-uniformity of these readings and inability to work through a shift, it is an indication that replacement is necessary.

Tables and Data

Ohm's Law for direct current

$$I = \frac{E}{R} \qquad R = \frac{E}{I} \qquad E = I \times R$$

where I = amperes;
E = volts;
R = resistance.

Formula for resistances in series

$$R_{(\text{Total})} = R_1 + R_2 + R_3 \quad \text{etc.}$$

Formula for resistances in parallel

$$R_{(\text{Total})} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \text{ etc.}$$

Determination of frequency of an alternator

$$\text{Frequency} = \frac{N \times S}{2}$$

where N = the number of field poles;
S = the speed of the armature in revolutions per second.

Fundamental frequency formula

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where f = frequency in cycles per second;
L = inductance of the circuit in henries;
C = capacitance of the circuit in farads.

Inductive reactance formula

$$X_L = 2\pi f L$$

where X_L = inductive reactance;
L = inductance in henries.

Capacitive reactance formula

$$X_c = \frac{1}{2\pi f C}$$

where X_c = capacitive reactance;
C = capacity in farads.

Ohm's Law for alternating current

$$I = \frac{E}{Z} \quad \text{or} \quad I = \frac{E}{\sqrt{R^2 + \left[\left(2\pi f L\right) - \left(\frac{1}{2\pi f C}\right)\right]^2}}$$

where I = current;
E = voltage;
Z = impedance (total of all oppositions).

Condensers connected in parallel

$$C_{(\text{Total})} = C_1 + C_2 + C_3 \quad \text{etc.}$$

Condensers connected in series

$$C_{(\text{Total})} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}} \text{ etc.}$$

WIRE TABLE, STANDARD ANNEALED COPPER
American Wire Gauge (B. & S.) English Units

Gauge No.	Diameter in mils at 20°C	Cross section at 20°C		Ohms per 1000 feet*			
		Circular mils	Sq. inches	0°C (32°F)	20°C (68°F)	50°C (122°F)	75°C (167°F)
0000	460.0	211600	0.1662	0.04516	0.04901	0.05479	0.05961
000	409.6	167800	.1318	.05695	.06180	.06909	.07516
00	364.8	133100	.1045	.07181	.07793	.08712	.09478
0	324.9	105500	.08289	.09055	.09827	.1099	.1195
1	289.3	83690	.06573	.1142	.1239	.1385	.1507
2	257.6	66370	.05213	.1440	.1563	.1747	.1900
3	229.4	52640	04134	.1816	.1970	.2203	.2396
4	204.3	41740	.03278	.2289	.2485	.2778	.3022
5	181.9	33100	.02600	.2887	.3133	.3502	.3810
6	162.0	26250	.02062	.3640	.3951	.4416	.4805
7	144.3	20820	01635	.4590	.4982	.5569	.6059
8	128 5	16510	01297	.5788	.6282	.7023	.7640
9	114.4	13090	01028	.7299	.7921	.8855	.9633
10	101.9	10380	.008155	.9203	9989	1.117	1.215
11	90.74	8234	.006467	1.161	1.260	1.408	1.532
12	80.81	6530	005129	1 463	1.588	1.775	1.931
13	71.96	5178	.004067	1.845	2.003	2.239	2.436
14	64.08	4107	.003225	2.327	2.525	2 823	3.071
15	57.07	3257	002558	2.934	3 184	3.560	3.873
16	50.82	2583	002028	3.700	4 016	4.489	4.884
17	45.26	2048	001609	4.666	5.064	5.660	6.158
18	40.30	1624	.001276	5.883	6 385	7.138	7.765
19	35.89	1288	.001012	7.418	8.051	9.001	9.792
20	31.96	1022	.0008023	9.355	10.15	11.35	12.35
21	28.45	810.1	.0006363	11.80	12 80	14.31	15.57
22	25.35	642.4	.0005046	14.87	16.14	18.05	19.63
23	22 57	509.5	.0004002	18.76	20.36	22.76	24.76
24	20.10	404.0	.0003173	23.65	25.67	28.70	31.22
25	17 90	320.4	.0002517	29.82	32.37	36.18	39.36
26	15 94	254.1	0001996	37.61	40.81	45.63	49.64
27	14.20	201.5	.0001583	47.42	51.47	57.53	62.59
28	12 64	159.8	.0001255	59.80	64.90	72.55	78.93
29	11.26	126.7	.00009953	75.40	81.83	91.48	99.52
30	10.03	100.5	.00007894	95.08	103.2	115 4	125.5
31	8 928	79.70	00006260	119.9	130.1	145 5	158.2
32	7 950	63.21	00004964	151.2	164 1	183 4	199.5
33	7.080	50.13	00003937	190.6	206 9	231.3	251.6
34	6.305	39.75	.00003122	240.4	260.9	291.7	317.3
35	5.615	31.52	.00002476	303.1	329.0	367.8	400.1
36	5.000	25 00	.00001964	382.2	414.8	463.7	504.5
37	4.453	19.83	.00001557	482.0	523.1	584.8	636.2
38	3.965	15.72	.00001235	607.8	659.6	737.4	802.2
39	3.531	12.47	.000009793	766.4	831.8	929.8	1012
40	3.145	9.888	.000007766	966.5	1049	1173	1276

* Resistance at the stated temperatures of a wire whose length is 1000 feet at 20°C.

TABLE 1—ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMPERES

Not More Than Three Conductors in Raceway or Cable

(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU (14–6) / Thermoplastic Type T (14–4/0) Type TW (14–4/0)	Rubber Type RH	Paper: Thermoplastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	Asbestos Var-Cam Type AVA Type AVL	Impregnated Asbestos Type AI (14–8) Type AIA	Asbestos Type A (14–8) Type AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	...
300	240	285	300	345	380	...
350	260	310	325	390	420	...
400	280	335	360	420	450	...
500	320	380	405	470	500	...
600	355	420	455	525	545	...
700	385	460	490	560	600	...
750	400	475	500	580	620	...
800	410	490	515	600	640	...
900	435	520	555	...	...	...
1,000	455	545	585	680	730	...
1,250	495	590	645	...	...	...
1,500	520	625	700	785	...	...
1,750	545	650	735	...	...	...
2 000	560	665	775	840	...	...

CORRECTION FACTOR FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C.	F.						
40	104	.82	.88	.90	.94	.95	...
45	113	.71	.82	.85	.90	.92	...
50	122	.58	.75	.80	.87	.89	...
55	131	.41	.67	.74	.83	.86	...
60	140	...	.58	.67	.79	.83	.91
70	158	...	.35	.52	.71	.76	.87
75	167	...	...	.43	.66	.72	.86
80	176	...	...	.30	.61	.69	.84
90	194	...	...	...	.50	.61	.80
100	212	...	...	...	...	.51	.77
120	248	...	...	...	...	...	.69
140	284	...	...	...	...	...	.59

See Notes Following Tables 1 and 2

TABLE 2—ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMPERES

Single Conductor in Free Air

(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU (14–6) / Thermoplastic Type T Type TW	Rubber Type RH	Thermoplastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	Asbestos Var-Cam Type AVA Type AVL	Impregnated Asbestos Type AI (14–8) Type AIA	Asbestos Type A (14–8) Type AA	Slow-Burning Type SB / Weather-proof Type WP Type SBW
14	20	20	30	40	40	45	30
12	25	25	40	50	50	55	40
10	40	40	55	65	70	75	55
8	55	65	70	85	90	100	70
6	80	95	100	120	125	135	100
4	105	125	135	160	170	180	130
3	120	145	155	180	195	210	150
2	140	170	180	210	225	240	175
1	165	195	210	245	265	280	205
0	195	230	245	285	305	325	235
00	225	265	285	330	355	370	275
000	260	310	330	385	410	430	320
0000	300	360	385	445	475	510	370
250	340	405	425	495	530	....	410
300	375	445	480	555	590	....	460
350	420	505	530	610	655	....	510
400	455	545	575	665	710	....	555
500	515	620	660	765	815	....	630
600	575	690	740	855	910	....	710
700	630	755	815	940	1005	....	780
750	655	785	845	980	1045	....	810
800	680	815	880	1020	1085	....	845
900	730	870	940	....	....	....	905
1000	780	935	1000	1165	1240	....	965
1250	890	1065	1130	....	....	....	....
1500	980	1175	1260	1450	....	....	1215
1750	1070	1280	1370	....	....	....	....
2000	1155	1385	1470	1715	....	....	1405

CORRECTION FACTOR FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C. F.							
40 104	.82	.88	.90	.94	.95	....	....
45 113	.71	.82	.85	.90	.92	....	....
50 122	.58	.75	.80	.87	.89	....	....
55 131	.41	.67	.74	.83	.86	....	....
60 140	....	.58	.67	.79	.83	.91	....
70 158	....	.35	.52	.71	.76	.87	....
75 167	....	.....	.43	.66	.72	.86	....
80 176	....	....	.30	.61	.69	.84	....
90 194	....	....	....	.50	.61	.80	....
100 212	....	....	....	....	.51	.77	....
120 248	....	....	....	....	....	.69	....
140 284	....	....	....	....	....	.59	....

See notes following Tables 1 and 2.

TABLE 4—NUMBER OF CONDUCTORS IN CONDUIT OR TUBING

Rubber Covered, Types RF-32, R, RH, RW and RU Thermoplastic, Types TF, T and TW One to Nine Conductors

Size AWG MCM	Number of Conductors in One Conduit or Tubing								
	1	2	3	4	5	6	7	8	9
18	½	½	½	½	½	½	½	¾	¾
16	½	½	½	½	½	½	¾	¾	¾
14	½	½	½	½	¾	¾	1	1	1
12	½	½	½	¾	¾	1	1	1	1¼
10	½	¾	¾	¾	1	1	1	1¼	1¼
8	½	¾	¾	1	1¼	1¼	1¼	1½	1½
6	½	1	1	1¼	1½	1½	2	2	2
4	½	1¼	*1¼	1½	1½	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1¼	2	2	2	2½	2½	2½
1	¾	1½	1½	2	2½	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	3	3	3	3½	3½	4
250	1¼	2½	2½	3	3	3½	4	4	4½
300	1¼	2½	2½	3	3½	4	4	4½	4½
350	1¼	3	3	3½	3½	4	4½	4½	5
400	1½	3	3	3½	4	4	4½	5	5
500	1½	3	3	3½	4	4½	5	5	6
600	2	3½	3½	4	4½	5	6	6	6
700	2	3½	3½	4½	5	5	6	6	...
750	2	3½	3½	4½	5	6	6	6	...
800	2	3½	4	4½	5	6	6	...	...
900	2	4	4	5	6	6	6	...	...
1000	2	4	4	5	6	6	...	...	...
1250	2½	4½	4½	6	6	...	...	...	...
1500	3	5	5	6	...	...	...	...	...
1750	3	5	6	6	...	...	...	...	...
2000	3	6	6	...	...	...	...	...	...

See Note 4 to Tables 1 and 2.

*Where a service run of conduit or electrical metallic tubing does not exceed 50 feet in length and does not contain more than the equivalent of two quarter bends from end to end two No. 4 insulated and one No. 4 bare conductors may be installed in 1-inch conduit or tubing.

TABLE 24—FULL-LOAD CURRENT*

Three-Phase A.C. Motors

	Induction Type Squirrel-Cage and Wound Rotor Amperes					Synchronous Type †Unity Power Factor Amperes			
HP	110V	220V	440V	550V	2300V	220V	440V	550V	2300V
½	4	2	1	.8	—	—	—	—	—
¾	5.6	2.8	1.4	1.1	—	—	—	—	—
1	7	3.5	1.8	1.4	—	—	—	—	—
1½	10	5	2.5	2.0	—	—	—	—	—
2	13	6.5	3.3	2.6	—	—	—	—	—
3	—	9	4.5	4	—	—	—	—	—
5	—	15	7.5	6	—	—	—	—	—
7½	—	22	11	9	—	—	—	—	—
10	—	27	14	11	—	—	—	—	—
15	—	40	20	16	—	—	—	—	—
20	—	52	26	21	—	—	—	—	—
25	—	64	32	26	7	54	27	22	5.4
30	—	78	39	31	8.5	65	33	26	6.5
40	—	104	52	41	10.5	86	43	35	8
50	—	125	63	50	13	108	54	44	10
60	—	150	75	60	16	128	64	51	12
75	—	185	93	74	19	161	81	65	15
100	—	246	123	98	25	211	106	85	20
125	—	310	155	124	31	264	132	106	25
150	—	360	180	144	37	—	158	127	30
200	—	480	240	192	49	—	210	168	40

For full-load currents of 208 and 200 volt motors, increase the corresponding 220-volt motor full-load current by 6 and 10 per cent, respectively.

*These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

†For 90 and 80 per cent P. F. the above figures should be multiplied by 1.1 and 1.25 respectively.

TABLE 21—FULL-LOAD CURRENT*
Direct-Current Motors

HP	115V	230V	550V
½	4.6	2.3	
¾	6.6	3.3	1.4
1	8.6	4.3	1.8
1½	12.6	6.3	2.6
2	16.4	8.2	3.4
3	24.	12.	5.0
5	40	20	8.3
7½	58	29	12.0
10	76	38	16.0
15	112	56	23.0
20	148	74	31.
25	184	92	38.
30	220	110	46.
40	292	146	61
50	360	180	75
60	430	215	90
75	536	268	111
100		355	148
125		443	148
150		534	220
200		712	295

*These values for full-load current are average for all speeds.

TABLE 22—FULL-LOAD CURRENT*
Single-Phase A.C. Motors

HP	115V	230V	440V
1/6	3.2	1.6	
¼	4.6	2.3	
½	7.4	3.7	
¾	10.2	5.1	
1	13.	6.5	
1½	18.4	9.2	
2	24.	12.	
3	34.	17.	
5	56.	28.	
7½	80.	40.	
10	100.	50.	21.
			26.

For full-load currents of 208 and 200-volt motors, increase corresponding 230-volt motor full-load current by 10 and 15 per cent, respectively.

*These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

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